Institute for Marine and Atmospheric research Utrecht

IMAU

BIENNIAL REPORT
2005/2006

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Universiteit Utrecht

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Utrecht University

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IMAU, Utrecht University
Princetonplein 5
3584 CC Utrecht
The Netherlands

Internet: http://www.phys.uu.nl/~wwwimau/
Tel: +31 (0)30 2533275
Fax: +31 (0)30 2543163
E-mail: IMAU@phys.uu.nl

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1. Introduction

In this biennial report we present an overview of the research and related activities over 2005 and 2006 of staff and students at IMAU, the Institute for Marine and Atmospheric research of Utrecht University.
The institute was formally established in 1991. However, we decided to celebrate its 40th anniversary in the fall of 2006 based on an informal start in 1966. Then, a small pioneering group was installed to set up a teaching programme in Meteorology and Physical Oceanography. It was based partly at KNMI, the Royal Netherlands Meteorological Institute, and partly at Utrecht University. Since then it has evolved into what is now a thriving research institute.
IMAU is the Marine and Atmospheric research section of the department of Physics and Astronomy from the Faculty of Science and the Coastal research section of the department of Physical Geography from the Faculty of Geosciences.

During the 40th anniversary, in November 2006, Hans Oerlemans handed over the scientific directorship of IMAU to Will de Ruijter. Hans was thanked for the clear and 'no-nonsense' way in which he has led the institute over the past period.

Climate change has taken a prominent position on the political and scientific agenda. Changes in the climate system, both natural and anthropogenic, may have far-reaching consequences for the global and, in particular, the Dutch society.
Climate variability at 'human' time scales is related to variations in the Ocean, Atmosphere (including its chemical composition) and Ice components of the system. Major impacts manifest themselves in the coastal zone.
Based on the latest climate change assessments by the IPCC (Intergovernmental Panel on Climate Change), large programmes are being developed for mitigation of and adaptation to the expected climate change. However, there are still large uncertainties in the projections of future climate. These need to be reduced. This is in particular the case at the regional scale for which adaptation programmes are being developed. Rapid changes in the ocean circulation, in ice volume and sea level and in the atmospheric composition that happened in the past may occur again. Reliable estimates of their likelihood needs basic dynamical studies and dedicated observations.
A main goal of the IMAU is to be one of the leading institutes in that research. We combine the expertise necessary to study the fundamental processes in the climate system and its main components and to study the response and dynamics of the coastal zone.

Because of the global scale of the ocean-atmosphere-climate system, we carry out our research in collaboration with many national and international partners. This is reflected in the relatively large number of our scientific publications with a multinational authorship.

Research at IMAU is organized around the themes Ice and Climate, Ocean Circulation and Climate, Atmospheric Dynamics and Boundary layer Meteorology, Atmospheric Physics and Chemistry and the Physical Geography and Oceanography of the coastal zone. Descriptions of these themes and several highlights of the research results are given in this report.
In the newly established Faculty of Science (the 'beta-faculty') at Utrecht University, IMAU is the leading institute responsible for the focal theme 'Climate and Global Change'. We collaborate in the Utrecht Centre for Geosciences (UCG) with Earth scientists and biologists on studies in the present and paleo climate systems.
At the national level we coordinate research in the Centre for Climate research (CKO) and the Netherlands Centre for Coastal research (NCK).

In 2005 the Atmospheric Physics and Chemistry staff of IMAU was for the first time complete. The group combines field observations, laboratory experiments and atmospheric models to study the varying atmospheric chemical composition. A lot of attention was drawn by the discovery of high methane concentrations over areas with living plants, also in the regular international news programs, because of its potentially large impact on the global greenhouse gas balance. It has stimulated a lot of research around the world into the possible mechanisms producing such methane levels.
Climate researchers from IMAU and KNMI joined forces in the ESSENCE project, an investigation into the signal to noise ratio in climate projections. It involves large ensemble simulations to study past and projected climate change over the period 1950-2100.
Together with scientists from NIOZ in the LOCO programme (Long term Ocean Climate Observations) we maintain an array of instrumented moorings across the Mozambique Channel. Aim is to study the variability in this section of the global thermohaline ocean circulation. This array forms part of a global network.
The coastal researchers initiated investigations in various estuarine and coastal systems around the world, resulting in international projects in the Ems estuary and in the coastal waters of northeast Kalimantan, Indonesia.
In 2006 preparations started for the International Polar Year (IPY, 2007-2009) in which, within the Netherlands Polar Programme, IMAU is responsible for the research theme Ice, Climate and Sea Level Change. IMAU projects will be dedicated to the stability and dynamics of Arctic Glaciers, including the Greenland Ice sheet. We will also be active in the Antarctic, providing automatic weather stations for operation in the coldest environment of the Earth.

Being a university institute IMAU plays an important role in educating meteorologists, physical oceanographers and climate scientists. At the graduate level IMAU is leading the national

Buys Ballot Graduate School for the study of fundamental processes in the Climate system. It is a joint school with the department of meteorology and air quality of Wageningen University. Associated members include KNMI, NIOZ and SRON, the Space Research Organization of the Netherlands. Highlights are the spring symposia, organized by the students, and the Buys Ballot days in the fall. At the international level a series of summer schools has been organized and led by IMAU scientists, as described in this report. These schools are highly rated and will be continued in the future.
The institute is also responsible for the master programme 'Meteorology, Physical Oceanography and Climate' which is directly coupled to our research programme. Based on the excellent level of the research, as judged by an international review committee, and its contribution to the profile of Utrecht University this teaching programme was selected as one of the few 'prestige masters' of the university.
It is our ambition to further strengthen this prestigious level of both education and research at IMAU.

A substantial part of the IMAU research has been made possible by external financial support from several branches of NWO, the Netherlands Organisation for Scientific Research (ALW, STW, WOTRO, NCF, SRON), the EU, BSIK, Shell/SenterNovem, the Japan Society for the promotion of Science and Rijkswaterstaat (RIKZ). We gratefully acknowledge all these funders. Finally, we like to thank our parent faculties, the Faculty of Science and that of Geosciences, and Utrecht University for their continued support of IMAU.

Will P.M. de Ruijter,
Scientific Director.

2. Faculty

Professors:

W.P.M. de Ruijter
H.A. Dijkstra (from 1-7-05)
H.E. de Swart (from 1-2-05)
P. Hoekstra
J. Oerlemans
T. Röckmann (from 1-5-05)

Professors (part-time):

J.D. Opsteegh (0.4)
J.T.F. Zimmerman (0.4)

External Professors (part-time/financed by):

B. v.d. Hurk (0.2)/Buys Ballot Leerstoel (from 1-3-05)
L.C. van Rijn (0.2) / WL-Delft Hydraulics

Associate Professors

M.R. van den Broeke
H. van Dop
B.G. Ruessink
P.J. van Leeuwen
R.S.W. van de Wal

Assistant Professors

B.T. Grasmeijer
A.J.F. Hoitink (0.2)
R. Holzinger (from 15-3-06)
A. Kroon (until 1-3-05)
G.J. Roelofs
L.A. te Raa
C.H. Tijm-Reijmer
A.J. van Delden
J.H. van den Berg (p.m.)

Supporting Staff

E. Bernsen (until 1-5-06)
M. H. Broeken (until 1-10-05)
P.P. Borsboom (from 15-7-06)
M.J.A. Bolder
W. Boot
D.B. van Dam
P.J. Jonker
M. van Maarsseveen
H. Markies
M. Portanger
C. Roosendaal
H. Snellen
G.M. Terra (from 1-3-06)
T. Tiemissen (until 1-9-06)
C. van der Veen

Secretaries

A. Andriessen (until 1-5-06)
J. Beltman (from 1-9-06)
I. Esser (until.1-7-06)
A.C. van den Berg (until 1-8-2005)
Y. Wouda

Co-manager

E.I. de Koning

3. Research Themes

Ice and Climate

faculty: J. Oerlemans
M.R. van den Broeke
R.S.W. van de Wal
C.H. Tijm-Reijmer

Ocean Circulation and Climate

faculty: W.P.M. de Ruijter
H.A. Dijkstra
J.T.F. Zimmerman
P.J. van Leeuwen
L.A. te Raa

Atmospheric Physics and Chemistry

faculty: T. Röckmann
G.J. Roelofs
R. Holzinger

Atmospheric Dynamics and Boundary Layer Meteorology

faculty: J.D. Opsteegh
B. v.d. Hurk
A.J. van Delden
H. van Dop

Physical Geography and Oceanography of the Coastal Zone

faculty: H.E. de Swart
P. Hoekstra
B.T. Grasmeijer
A.J.F. Hoitink
A. Kroon
B.G. Ruessink
J.H. van den Berg
L.C. van Rijn

3.1 Ice and Climate

The cryosphere (all ice and snow, including permafrost) constitutes an important component of the climate system. Changes in the state of the cryosphere can have large consequences for human activities (infrastructure affected by thawing of permafrost, ice avalanches, outburst of glacial meltwater lakes, new shipping possibilities due to reduced sea ice, problems with reduced snow cover in ski areas, etc). For the Netherlands the most important aspect of changes in the cryosphere is the relation between glacier volume and sea level. It is thus not surprising that the interaction between glaciers / ice sheets and climate is an important topic of research at IMAU. The Ice and Climate research group studies glaciers and ice sheets with theoretical and numerical models, with in situ data collection with specialised equipment, and with analysis of data provided by a range of satellite instruments.

Several of the activities listed above were performed with support of the Netherlands Polar Program (NPP). In an international evaluation, of which the report appeared in 2005, the polar research performed by the Ice and Climate group at IMAU was assessed as an excellent contribution. Our group will continue to lead the theme, Ice, Climate and Sea Level of the NPP, and has contributed.

During the past years we have used numerical models of ice sheets to study the evolution of continental ice sheets during the last millions of years, with a focus on the interpretation of oxygen isotope records from marine sediments. Much attention was also paid to the interaction between ice sheets and the solid earth and the consequences for the interpretation of past sea-level changes. Resolution in numerical ice-sheet modelling remains a critical issue and we found that extreme care has to be taken in the formulation of boundary conditions.

A new topic is the dynamics of tidewater glaciers. Many of the world's larger glaciers are tidewater glaciers: they end in the sea and produce large amounts of icebergs. The response of these glaciers to climate change is a major uncertainty in projection of future sea-level rise due to changes in glacier volume. Models of different complexity were developed and compared. A significant effort was made to set up an international research programme (GLACIODYN) as a contribution to the International Polar Year (IPY). Much more data are needed to validate models of tidewater glaciers. Parameterisation of the calving process and a better representation of sliding are the most critical issues.

The ongoing operation of automatic weather stations on the Morteratschglacier in Switzerland, on Hardangerjøkulen and on Storbreen in Norway and in Greenland and Antarctica has been successful. We have continued our mass balance measurements on the west-Greenland ice sheet; with 16 years of observations it is by far the longest in situ mass balance record from the Greenland Ice Sheet. In support of these observations, automatic weather stations are operated along the mass-balance transect (the "K-transect"). These stations have delivered important data for the interpretation of the mass balance results. In addition, we have collected two years of turbulence data from the Greenland ablation zone, to assess the seasonal variability of the surface roughness. Three AWS in Antarctica have continued to operate near the Swedish stations Wasa and Svea and the German station Kohnen.

In the field of regional climate and mass-balance modelling, important progress has been made with the modelling of Antarctic surface mass balance. In the reporting period, a start has been made with similar work over Greenland in the framework of RAPID international research program.

Climatic interpretation of glacier length records

From different parts of the world there is a wealth of information on glacier fluctuations. Systematic and precise measurements of glacier area and volume are relatively new (the past few decades). However, the length of a valley glacier is a relatively simple parameter to measure or to infer from sketches, paintings and early maps. In many cases moraines and trim lines provide very useful additional information. A number of 169 records of glacier length were compiled from various sources. The core of the dataset comes from the files of the World Glacier Monitoring Service (WGMS, Zürich). Records were included from glaciers in Patagonia, southern Greenland, Iceland and Jan Mayen. Additional information was taken from the Satellite Image Atlas of Glaciers of the World (U.S. Geological Survey) and from reports of the Swiss Academy of Sciences. The character of the records differs widely (Fig. 1). Some start in 1600 and have typically 10 data points until 1900, and more afterwards. Other records start around 1900, but have annual resolution throughout.

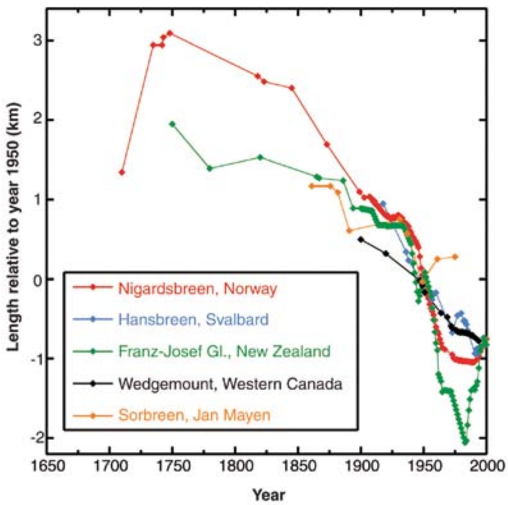


Figure 1

Examples of glacier length records from different parts of the world. Each symbol represents a data point.

From Oerlemans J., Extracting a climate signal from 169 glacier records. Science 308, 675-677, (2005).

Like other climate proxies, glacier length fluctuations are the product of variations in more than one meteorological parameter. Glacier mass balance depends mainly on air temperature, solar radiation and precipitation. Extensive meteorological experiments on glaciers have shown that the primary source for melt energy is solar radiation, but that fluctuations in the mass balance trough the years are mainly due to temperature and precipitation. To compensate for the mass loss due to a 1 °C warming, a 25 % increase in annual precipitation is typically needed, which is a large number. Since precipitation anomalies normally have a smaller spatial and temporal scale than temperature anomalies, it is likely that glacier fluctuations over decades to centuries on a continental scale are primarily driven by temperature.

To calculate with a simple model (first-order linear response equation) an annual temperature record that can explain the fluctuations of a certain glacier, two parameters characterising that glacier are needed: the response time τ, and the climate sensitivity c (conveniently expressed as the decrease in equilibrium glacier length for a 1 °C warming). It is possible to estimate c and τ with glacier models; c and τ depend mainly on the surface slope of the glacier and the climatic regime. Steeper glaciers have a smaller response time and are less sensitive. Glaciers in a wet climate are also faster, but at the same time are more sensitive than glaciers in a dry climate.

The global mean temperature as reconstructed from the 169 glacier length records is shown in Fig. 2. It is a combination of an area-weighted mean for the period 1834 – 1990 and a stacked record for all glaciers before 1834 (because before this year there is no record for all regions as defined above). It should be stressed that the temperature reconstruction presented here is fully independent of other sources (proxy or instrumental).

To make an error estimate 100 alternative temperature reconstructions were generated by subsampling and varying the parameters c and τ. The standard deviation calculated from this set of reconstructions is taken as an estimate of the error in the best estimate based on all records. This standard deviation has been smoothed in time. Changes in the resulting bandwidth reflect first of all the effect of the steadily increasing number of glacier records.

The derived global temperature record is in broad agreement with other reconstructions, and for the last part also with the instrumental record. However, the glacier reconstruction shows a some what larger amplitude on the century time scale. Because glaciers need time to react and the number of records drops sharply after 1995, the warming seen in the instrumental record over the last 15 years is not yet picked up by the reconstruction.

Temperature curves appear to be very similar for glaciers with low and high median elevation. Low and high glaciers are classified as glaciers with median elevation below and above 2850 m respectively. Although the evidence is not conclusive because only a limited altitudinal range is considered, the glacier record does not show any sign of a height dependence of the global warming signal.

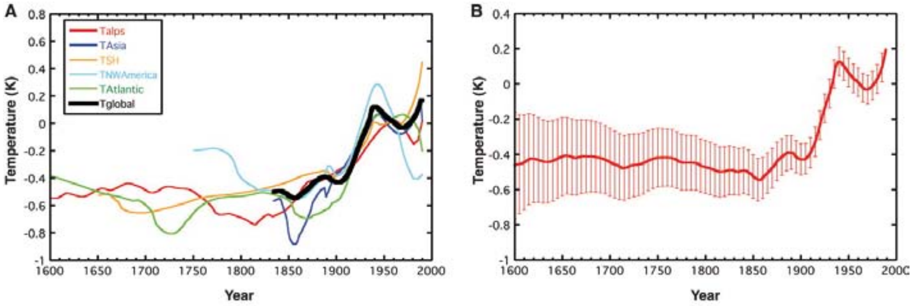


Figure 2

Reconstructed global mean temperature anomaly. Due to the delayed response of glaciers and the strongly decreasing number of records, temperature cannot be reconstructed for the period after 1990.

Climate reconstruction from the EPICA Dronning Maud Land ice core

High-resolution climate information obtained from the second EPICA (European Program for Ice Coring In Antarctica) revealed a strong link between climate oscillations in Antarctica and Greenland. The EPICA core drilled at Kohnen base in Dronning Maud Land (DML) represents South Atlantic climate at a resolution comparable with Greenland ice core records.

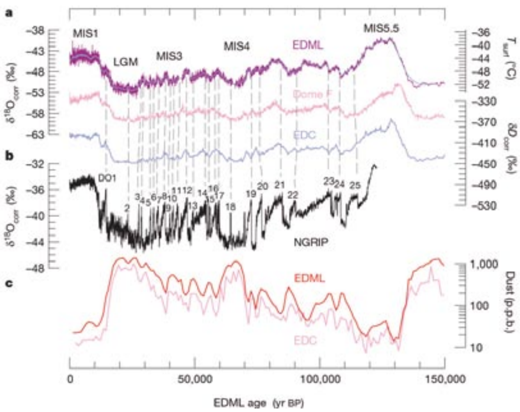


Figure 3

Antarctic stable isotope records show synchronous millennial variations during the last glacial, whereas rapid variations are encountered in Greenland. EPICA DML (EDML), EPICA Dome C (EDC) (blue), Dome F (pink) and Greenland North GRIP (NGRIP, black) oxygen isotope record over the past 150.000 yr. The temperature axis on the right side indicates approximate surface temperatures Lower curves show mineral dust records of the EDML (red) and EDC12 (pink) ice cores at 1,000-yr resolution; these dust records were used for synchronization of the cores.

From EPICA Community members, J. Oerlemans, M. R. van den Broeke, R. S. W. van de Wal, One-to-one coupling of glacial climate variability in Greenland and Antarctica, Nature 444, 195-198, (2006) After methane synchronization with an ice core from North Greenland (NGRIP), the oxygen isotope record from the Dronning Maud Land ice core shows a one-to-one coupling between all Antarctic warm events and Greenland Dansgaard–Oeschger (D-O) events by the bipolar seesaw (Figure 3). The bipolar seesaw represents the drainage of heat from the Southern Atlantic Ocean when the meridional overturning circulation in the North Atlantic is more active (warmer Greenland, slowly cooling Antarctica). For the first time, two high-resolution records could be used to also compare timing and amplitude of the D-O events. The amplitude of the Antarctic warm events is found to be linearly dependent on the duration of the concurrent stadial in the North, suggesting that they all result from a similar reduction in the meridional overturning circulation. The hypothesis that the southern and northern hemisphere climates are intimately linked through Atlantic Ocean heat transport (the See Saw hypothesis) is conformed by these observations.

Reconstruction of temperature over the last million years

New avenues have been explored in ice sheet modelling by the development of an inverse method which generates air temperature and sea level from a marine oxygen istope record. The model is based on the idea that on glacial-interglacial time scales the main contribution to changes in the marine benthic oxygen isotopic record originates from two sources, namely (i) the change in ice volume in the Arctic, and (ii) the deep-sea temperature. Both quantities depend on the mid-latitude to Arctic surface air temperature. In the model the two contributions to changes in the oxygen record are separated by means of an inverse modelling approach. Oxygen isotopes are treated as passive tracers in the ice and a simple relation between air temperature and deep-sea temperature is used. Results of the approach are mutually consistent records of surface air and deep-ocean temperature, sea level and ice volume. One of the key findings is that surface air temperatures are approximately 17˚C lower in the Northern Hemisphere during extreme glacial periods (Figure 4), which is somewhere in between estimates based on isotope studies from ice cores, and temperature inversions from borehole loggings in ice, which are in addition both considered to be local values. The temperature curve shown in Figure 4 is assumed to be representative for the mean temperature between 40˚N and 80˚N, and compares favourably with the Dome C reconstruction based on δD measurements (EPICA), suggesting a global coherence between the Northern and Southern Hemispheres on multi-millennium time scales. The start of glacial periods is characterized by a rapid cooling of 4˚C per kyr and mean temperatures are estimated to be 9.4 ˚C below present-day values. The advantage of the new approach is that marine benthic records are analysed in a model framework that is based on conservation of isotopic mass and the physical principles of ice-sheet modelling.

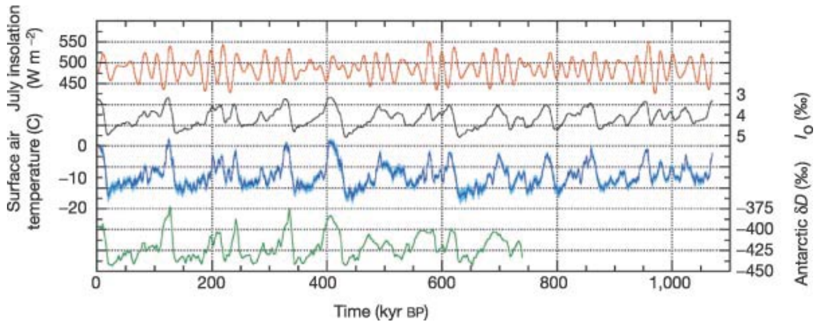


Figure 4

Reconstruction of Northern Hemisphere surface air temperature over the last 1.070 Kyr (blue, third curve). (Bintanja et al. 2005). Also shown are July insolation at 65°N (red, upper curve), the input marine oxygen isotope stack (black, second curve) and Antarctic δD (green, lower curve). The blue error bar shows a temporal varying uncertainty based on model and input uncertainties.
From Bintanja, R., R. S. W. van de Wal, J. Oerlemans, Modelled atmospheric temperatures and global sea levels over the past million years, Nature, 437, 125-128 (2005)

On bedrock adjustment in ice sheet models

The isostatic depression of the solid earth as a result of ice loading can reach about one third of the ice thickness, and so crustal subsidence of up to 1 km is common for large ice sheets. Local precipitation and melt both depend on surface elevation, so it is clear that an accurate treatment of the vertical deformation due to isostatic adjustment is important for the mass balance of ice sheets. A Cartesian model with an elastic lithosphere and a single relaxation time is the most widely used earth model in glaciological applications. This model is easy to implement and computationally efficient, and it is generally assumed that it is adequate to describe the interaction of ice sheets and the solid earth. We have performed several experiments, which clearly showed that this assumption is incorrect, at least for the Fennoscandinavian ice sheet. Figure 5 shows simulated ice thickness in Eurasia at the Last Glacial Maximum (LGM) for two different earth models: (i) a spherically symmetric viscoelastic self-gravitating earth model (SGVE, left plot) and (ii) a Cartesian elastic lithosphere with a single relaxation time (ELRA, right plot). In the SGVE model viscosities have been tuned for Eurasia, whereas the lithospheric strength and relaxation time of the ELRA model were tuned such that the LGM ice volume fitted the ice volume as predicted by the SGVE model. The distribution of the ice is clearly very different. By adopting different combinations of lithospheric strength and relaxation time, the fit in ice distribution can be improved. However, the ice volume at the LGM is then underestimated by 30 percent. Based on this finding and some additional tests we concluded that the SGVE and the ELRA models are fundamentally incompatible. The SGVE model represents a physically more comprehensive treatment of the earth response, hence we recommend to use this model rather than the widely adopted ELRA model, despite the additional computational effort.

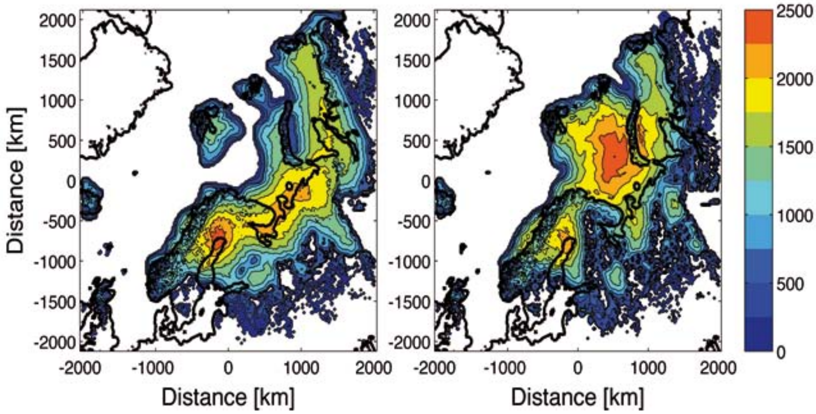


Figure 5

Ice thickness (in m) at LGM for the SGVE model (left) and ELRA model (right). Note the different location and height of the highest point.

From Berg, J.v.d., G. Milne, R. S. W. van de Wal, J. Oerlemans, submitted: The effect of earth parameters on the evolution of the Fennoscandinavian ice sheet

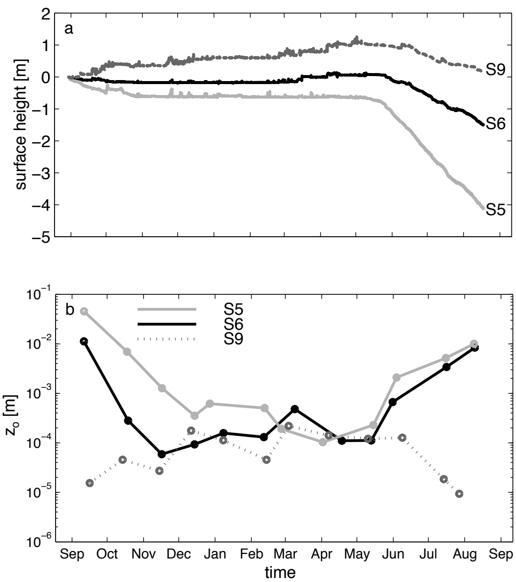


Figure 6

a) Surface height observations from the sonic height ranger;

b) momentum roughness lengths from S5, S6 and S9 as a function of time with every dot representing a bin averaged median value of the data (bin size = 30 days).

From Smeets, C.J.P.P. and M. R. van den Broeke, submitted: Temporal and spatial variation of momentum roughness length in the ablation zone of the Greenland ice sheet, Boundary-Layer Meteorology

Seasonal variations of roughness length in the Greenland ablation zone

For the response of the Greenland ice sheet to climate change the narrow ablation zone is of particular importance, since it accommodates the yearly net surface ice loss. In models the bulk-aerodynamic method is often used to calculate the turbulence surface fluxes for which momentum roughness length (z0) is a key parameter. This work presents, for the first time, spatial and temporal variations of z0 in the ablation area of the Greenland ice-sheet using year-round data from three AWS and one Eddy-Correlation (EC) mast. S 5 (lower ablation zone, 350 m asl), AWS 6 is situated in the middle ablation zone (app. 1000 m asl) and AWS 9 close to the equilibrium line (1500 m asl).

An important first result is that all snowfall in the lower ablation zone collects in gullies and crevasses, so that the low-albedo ice remains at the surface and no change in surface height is detected, in contrast to sites higher on the ice sheet (Figure 6a). This effect should be taken into account in mass balance models of the Greenland ice sheet.

The year-round values of z0 throughout the ablation area reveal very large variations (Figure 6b). In the lower ablation area, during summer melt, large ice-hummocks are formed increasing z0 above 1 cm. During winter z0 reduces to about 10–4 m due to snow accumulation and redistribution. The overall year-round variation of z0 in the lower ablation area is a factor of 500. At the end of summer melt, rough ice covers most of the ablation area up to 60 km from the ice edge with z0 > 0.005 m. At the beginning of winter, z0 decreases surprisingly fast in the lower ablation area. Single snow events have the potential to lower z0 by a factor of 20 to 50, even in case of a very rough ice surface. This suggests that for the total surface drag the abundant small-scale ice hummocks dominate over the less frequent large domes and deep gullies.

3.2 Ocean Circulation and Climate

The general objectives within this research theme are (i) to contribute to a more detailed description of the present large-scale ocean circulation including its variability; (ii) to identify physical processes maintaining this circulation, and (iii) determine the role of the ocean circulation in the evolution of the climate system. The research effort has been divided in two main projects.

The first research project focuses on the 'South Atlantic inter-ocean exchange and its global connection'. One of the key areas in the global ocean circulation is the inter-ocean connection between the Indian and the South Atlantic Oceans, near the southern tip of the African continent. The major western boundary current of the Indian Ocean, the Agulhas Current overshoots the African continent but retroflects back into the Indian Ocean. Occasionally large rings are shed from the retroflection into the South Atlantic Ocean, transporting large amounts of excess heat and salt. In 2005-2006 observations from the ACSEX (Agulhas Current

Sources Experiment) and LOCO (Long-term Ocean Climate Observations) projects have been further analyzed and interpretations supported by numerical simulations have been made, in close cooperation with researchers from the Royal NIOZ. Within LOCO more observations have been carried out in the Mozambique Channel to study the transport and variability of the upstream sources of the Agulhas. These observations will be combined directly with high-resolution ocean models using advanced data-assimilation techniques.

The second research project focuses on the 'Stability and variability of the ocean circulation'. Within this project, the large-scale ocean circulation is investigated both by more traditional methods and by using elements from dynamical system theory. In particular, equilibria of the large-scale ocean circulation as well as the stability of these equilibria are investigated, with applications to potential sources of present and past climate changes. For example, a theory for the North Atlantic Multidecadal Variability in the present climate has been developed, and the Atlantic-Pacific flow reversal in the early Miocene has been studied in detail.

In cooperation with researchers from the KNMI the ESSENCE project has been initiated. In this project, climate change over the period 1950-2100 has been studied using ensemble simulations with a coupled climate model. The results indicate that the observed warming over the last 60 years in many parts of the world is statistically undistinguishable from the estimated warming caused by increased greenhouse gas concentrations.

From the Indian Ocean to the global thermohaline circulation.

Satellite altimeter observations of sea-surface height (SSH) variability of the southwest Indian ocean show a region of maximum variability in the Agulhas retroflection and Return Current that is connected to the north with the variability in the Mozambique Channel and that around the southern tip of Madagascar (Fig. 1). Eddies formed in the northern Mozambique Channel and south of Madagascar propagate and, on arrival at the Agulhas Retroflection, affect the shedding rate of Agulhas rings.

The contribution of these Agulhas rings to the global thermohaline circulation has been investigated in an adiabatic high-resolution model of the Atlantic Ocean. This revealed how the ring signal is carried through the Atlantic basin by Rossby- and Kelvin waves, and that changes in the thermohaline circulation due to the adiabatic contribution of these rings are considerable. Furthermore, the recent literature on the propagation mechanism of ocean rings has been reviewed, and a more general propagation mechanism has been proposed.

Interannual variations of the rate of eddy formation in the Mozambique Channel appear as a lagged response to the Indian Ocean Dipole (IOD) events. These generate large-scale SSH-anomalies that propagate westward as forced Rossby waves in the latitude band around 10º S. They arrive at the coast of Madagascar about one year after each IOD event. Subsequently, the strength of the currents through the narrow section of the Mozambique Channel varies, and so does associated eddy activity, around 17ºS.

In the East Madagascar Current we discovered eddies in the hydrographic sections that have their maximum salinity and velocity signature at the base of the thermocline. They could be traced back to the highly evaporative area in the south-east Indian Ocean.

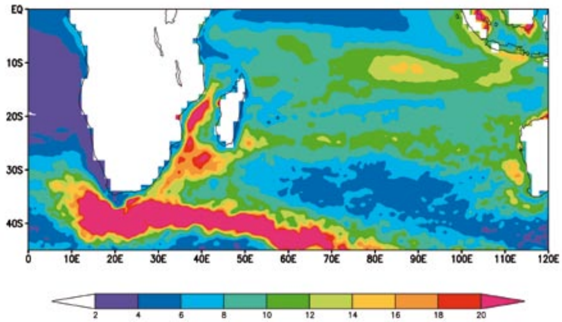


Figure 1
RMS of the sea surface height (in cm) in the South Indian Ocean from the combined T/P-ERS data set.

The upper-ocean eddy activity in the separation region of the East Madagasacar Current, south of Madagasacar, appears controlled by variability generated in the subtropical band of enhanced variability around 25ºS east of Madagascar. There, we discovered a surface intensified eastward jet, concentrated mostly in the upper 300 m (which was named the Subtropical Indian Ocean Countercurrent (SICC). It is probably a frontal jet along the northern branch of the subtropical front.
The SICC flows in direction opposite over the SEC and becomes baroclinically unstable at a range of unstable frequencies around 4-5 times per year, consistent with the observed peak in the SSH spectrum in the western part of the variability band.

Signal-to-noise ratio in climate projections

The main aim of the ESSENCE project was to compute an adequate estimate of the statistics of internal climate variability and hence be able to obtain a good signal-to-noise ratio for the forced signal due to the increase of greenhouse gases. In the project, a 17 member ensemble simulation of climate change in response to the SRES-A1b scenario was carried out using the ECHAM5/MPI-OM climate model. The relatively large size of the ensemble enabled us to better distinguish the forced signal from internal variability. We showed that in large parts of the world the observed warming over the last 60 years is statistically indistinguishable from the warming forced by increased greenhouse gas concentrations.
A great advantage of a large ensemble is the large noise reduction that can be achieved by averaging over all ensemble members. We were able to determine the year in which the forced signal (i.e., the trend) in the surface temperature emerges from the noise. (Fig. 2). A student t-test, in which the trend over a particular period is compared with the standard deviation of the noise, was used.

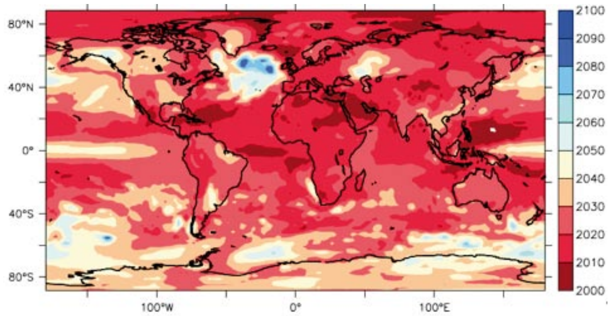


Figure 2
Year in which the trend (measured from 1980 onwards) of the annual-mean surface temperature emerges from the weather noise at the 95%-significance level.

The earliest detection times are found off the equator in the western parts of the tropical oceans, where the signal emerges as early as around 2000 (and for some regions even earlier) from the noise. In these regions the internal variability is extremely low while the trend is only modest. A second region with an early detection is the Arctic, in which the trend is very large due to the decrease of the sea-ice. The longest detection times are found along the equatorial Pacific where, due to El Nino, the variability is very high, as well as in the Southern Ocean and the North Atlantic, where the trend is very low.

Data assimilation for nonlinear dynamics.

Data assimilation is the combination of numerical models and observations to integrate our knowledge of the dynamical equations and the actual state of the ocean. In this way more can be learned about the ocean dynamics of the real ocean, about model deficiencies, and model parameters can be estimated. At IMAU we focus on data-assimilation methods that can deal with highly nonlinear numerical models, since the actual ocean is highly nonlinear. To this end we use Monte-Carlo methods, also called particle methods, in which several model runs are performed to obtain a representation of the probability density structure of the model, given the model uncertainties. A serious problem is that the number of model runs, or particles, has to be much larger than is affordable on the largest supercomputers of the world. Several optimizations of the particle methods have been developed at IMAU over the last few years. One of them uses corrections to the model state that are local in space and time, so-called Local Sequential Importance Sampling. The effect of these local corrections is that the effective size of the ensemble of particles increases roughly with the ratio of the total model area over the area used in the local correction, which is typically of the order of 1000. An example is presented in figure 3, in which we estimated the horizontal mixing parameter in a global version of the state-of-the-art ocean circulation model OPA, based on model derived sea-surface height observations, in anticipation of the Gravity and Ocean Circulation Experiment (GOCE) satellite. The model has about 500,000 grid points This problem is highly nonlinear since the relation between the sea-surface height and the mixing parameters is not local and very complicated. The large-scale features of the reference are well represented, but at smaller scale large differences occur. The patchiness of the data-assimilation result is due to the noise added to the geoid observations (1 cm uncorrelated in space). The interpretation of this result is that sea-surface height observations alone are not sufficient to constrain the horizontal mixing parameters of the ocean model.

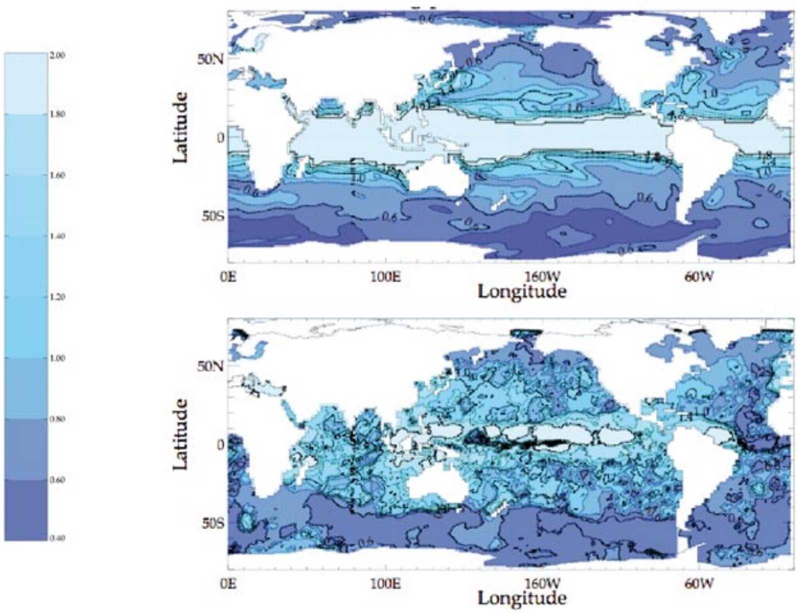


Figure 3

Horizontal mixing parameters in the global ocean circulation model OPA. The upper panel shows the reference, the lower panel the estimation of that reference using sea surface height as observations. Units are 1000 m2/s.

Theory of the North Atlantic Multidecadal Variability

The North Atlantic sea-surface temperature (SST) appears to have a distinct signal of multi-decadal variability. The difference of the SST pattern between the relatively warm years 1950-1964 and the relatively cold years 1970-1984 shows negative anomalies near New Foundland and positive anomalies over the rest of the basin (Fig. 4a). We have proposed an explanation of the physical processes responsible for the time scale and the spatial pattern of the Atlantic Multidecadal Variability (AMV). Our approach involved the analysis of solutions of a hierarchy of models. In the highest member of the model hierarchy, which is the GFDL-R30 climate model, multidecadal variability is found as a dominant statistical mode of variability (Fig. 4b). In the lowest member of the model hierarchy, which is an ocean-only model for flow in an idealized basin, the variability shows up as a multidecadal oscillatory mode which is able to destabilize the mean thermohaline circulation (Fig.4c). The spectral origin of this mode is a merger of so-called SST modes. The connection between results in both models was established by tracing the spatial and temporal expression of the multidecadal mode through the model hierarchy while monitoring changes in specific quantities (mechanistic indicators) associated with its physics. The proposed explanation of the properties of the AMV was eventually based on the changes in the spatial patterns of variability through the model hierarchy. The time scale derives from the east-west travel time of a density anomalies over the Atlantic basin, whereas the spatial pattern results from a deformation of the pattern of the multidecadal mode due to continental boundaries.

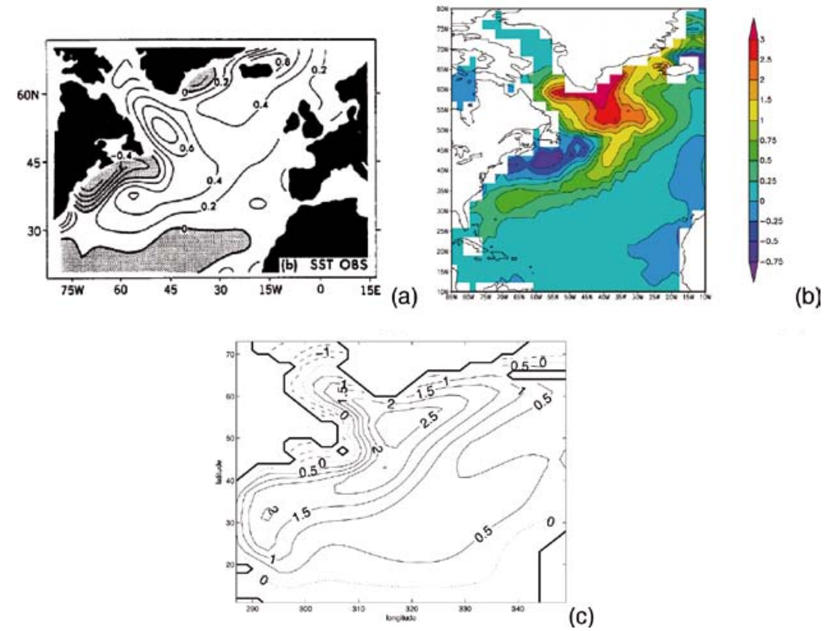


Figure 4

(a) Observed pattern of the difference in North Atlantic sea-surface temperature (in C) between the relatively warm period 1950-1964 and the relatively cold period 1970-1984 (Kushnir, J. Climate, 7, 141, 1994).

(b) Difference in SSTs between the maximum and minimum meridional overturning for the statistical multidecadal mode in the GFDL-R30 model.

(c) Difference in SSTs between maximum and minimum meridional overturning for the multidecadal oscillation in an idealized ocean-only model. From Dijkstra, H. A., L.A. te Raa, M. Schmeits and J. Gerrits, On the physics of the Atlantic Multidecadal Oscillation, Ocean Dynamics, 56, 36-50, (2006).

The Atlantic-Pacific flow reversal in the early Miocene

Using a fully-coupled climate model (CCSM1.4), we have simulated the Earth's climate state in the late Oligocene and the early Miocene. The model results show the existence of a flow reversal through the Panama Seaway between these periods (Fig. 5). This flow reversal is induced by global tectonic changes related to the widening of the Southern Ocean passages and the closing of the Tethys Seaway. As indicated by previous model studies it mainly involves the wind-driven ocean circulation. The climatic consequences of the flow reversal are that the upper waters of the Caribbean Sea and the tropical Atlantic become substantially cooler and fresher. This may have influenced the Caribbean fauna, in particular the warm-water coral species. The global meridional overturning circulation is not affected by the flow reversal, as it does hardly change from the Oligocene to the Miocene simulation. However, the meridional overturning is different from the present-day state, as there is deep water formation in both the North Atlantic and the North Pacific Oceans.

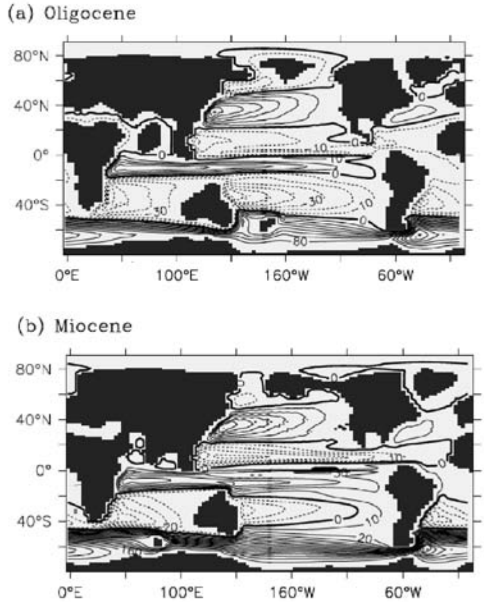


Figure 5

Barotropic streamfunction for (a) the Oligocene simulation (30 Ma) and (b) the Miocene (20 Ma) simulation. The data are averaged over the last 40 years of the simulation. Solid lines indicate positive stream function (clockwise gyres), dashed lines negative stream function (anti-clockwise gyres). Contour intervals are 10 Sv. From A. S. Von der Heydt and Dijkstra, H. A., The Effect of Ocean Gateways on the Global Ocean Circulation in the Late Oligocene and Early Miocene, Paleoceanography, 21, PA1011, doi:10.1029/2005PA001149, (2006).

3.3 Atmospheric Physics and Chemistry

Environmental issues such as air pollution, stratospheric ozone depletion and global warming are closely linked to anthropogenic activities and a changing chemistry of the atmosphere. The Atmospheric Physics and Chemistry group at IMAU combines field measurements, laboratory measurements and atmospheric models to study the impact of chemical, physical and dynamical processes on the atmospheric chemical composition.

The key experimental expertise of the group is the development and application of isotope techniques to atmospheric chemistry. The isotopic composition of trace compounds gives information about its sources, sinks and chemical reaction pathways in the atmosphere. We operate a large isotope laboratory with numerous preparation and extraction devices coupled to isotope ratio mass spectrometers. Each analytical system is specially designed to determine concentration and isotopic composition of a certain atmospheric component, and we have

systems operational for isotope measurements on CH_4, N_2O, H_2O, H_2 and CO_2. Further methods for isotope analysis on organic compounds and aerosols are under development. Samples are collected at many stations around the globe and from environments reaching from the stratosphere to polar ice cores, often in the framework of large international or national projects (e.g. BARCA-LBA, EUROHYDROS, SCOUT-O3, NEEM).
The models simulate distributions of, for example, aerosols and cloud microphysical parameters, and of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) and ozone (O_3). The results can be used to assess the effect of the changing abundance of trace species on the Earth's climate. For that purpose a coupled chemistry-climate model and a chemistry-transport model are available. Additionally, more detailed box-models and 1D-models of, e.g., radiative transfer, atmospheric chemistry, or cloud microphysics are used for process oriented studies of the climate system. The model performance is evaluated by comparing simulation results with measurements made at the surface, from aircraft, or from satellite platforms. The modelling research projects are closely coupled to other research groups in the Netherlands (KNMI, SRON, TNO, ECN) and in Europe (e.g., the Max Planck Institutes for Chemistry (MPI-C) and for Meteorology (MPI-M) in Germany, the Joint Research Centre in Italy, and the University of Crete in Greece).

Investigation of the global H_2 budget and the potential impact of a hydrogen economy on atmospheric chemistry and composition

Hydrogen may well be the fuel of the future. It is not a direct greenhouse gas itself, and it burns cleanly to produce only water as an exhaust. Hydrogen emissions are not, however, without potential consequences for the chemistry of the atmosphere and – via formation of water vapor – for stratospheric ozone. The details of those effects can be estimated only roughly because the atmospheric cycle of hydrogen has been studied little in the past. Given the potential impact of a global hydrogen economy on atmospheric hydrogen, there is now interest to understand the present budget of H_2 before such a drastic change in the global cycle takes place. EUROHYDROS is a recently started FP6 EU project aimed at the investigation of the atmospheric cycle of molecular hydrogen (H_2). It comprises an observational network with 12 continuous measurements sites in Europe, 7 flask sampling sites in Europe and 6 global flask sampling sites. Concerning the European sites, a range of observation from clean air stations for measurements of atmospheric background to moderately polluted (e.g. urban outflow) and urban (i.e. polluted) sites was chosen. This will enable to improve the understanding of hydrogen in the global background atmosphere and of the impact of European emissions on the present day atmosphere, e.g. using local modeling techniques and radon flux calculations. The APCG group from IMAU contributes with measurements of the isotopic composition of H_2. This is an excellent tool to quantify the individual source and sink terms in the budgets, and it will be carried out for the first time on a large scale.
Within an associated national project we will also determine precisely the isotope source signatures of the most important sources and sinks.

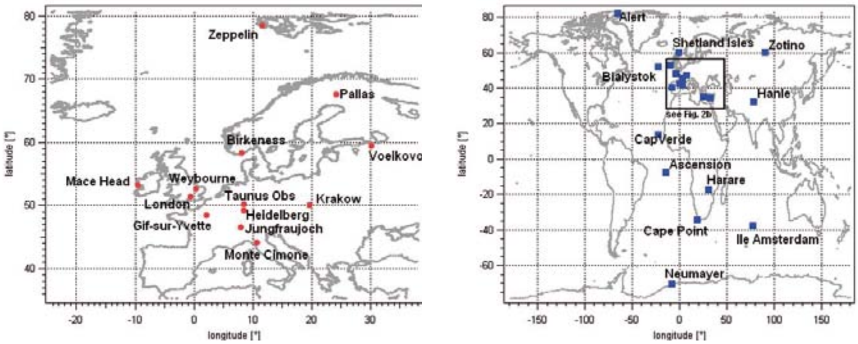


Figure 1

Eurohydros continuous (left) and flask measurement stations. The ACPG group will analyze the isotopic composition of flask samples from three global and three European flask sites, as well as various source a sink studies.

Investigation of the tropical sources of CH_4 – emissions from plants

The strong greenhouse gas methane is important for the radiative balance of the earth and plays a central role in atmospheric oxidation chemistry. Therefore, its atmospheric cycle, including natural and anthropogenic sources has been studied intensively. It has become established textbook knowledge that most of the methane produced from natural sources should originate from biological processes in anoxic environments. However, we have recently demonstrated that methane can be formed in situ in terrestrial plants under normal oxic conditions by a hitherto undiscovered process. First global estimates indicate that emissions from plants are an important methane source, which has been overlooked in the past.

We are presently attempting to identify and quantify methane emissions from plants using a comprehensive approach on different scales. This includes global and regional atmospheric observations and modelling, measurements on ice core air, emissions from different plant species under various environmental conditions and studies on the underlying production mechanisms of methane and other organic trace gases in plants. We are using high precision concentration and isotope measurements, as well as flux measurements to study those emissions as well in the laboratory as in the field. The fieldwork is associated with the international BARCA/LBA campaign in Brazil in fall 2007. We will setup a dedicated atmospheric measurement program using complementary techniques at suitable locations to identify the source that causes the CH_4 elevations observed recently from satellite platforms and to identify and better constrain methane emissions from vegetation. Suitable measurement stations are selected with the help of atmospheric models. The plant experiments will provide detailed process information and emission estimates, which are needed to adequately incorporate the plant source in models. All results will be integrated in global models available at IMAU to better constrain the magnitude of the vegetation source, which will lead to a better understanding of the past, present and future methane cycle.

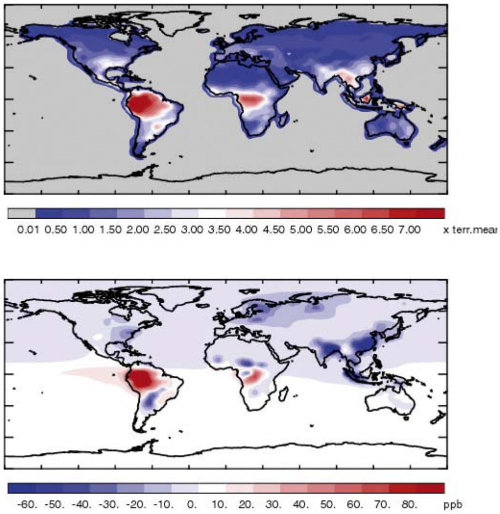


Figure 2

Top: CH_4 emissions from vegetation as implemented in the model by Houweling et al., [Geophys. Res. Lett., 33, 2006] using a parameterization based on the leaf area index.

Bottom: The corresponding atmospheric signal from those plant emissions relative to a reference scenario without plant emissions. The positive values are a signature of the vegetation emissions, primarily over the Amazon region and the African rainforest. In order to keep the budget closed one has to reduce emissions from other sources in the model when vegetation emissions are introduced. This causes the negative signals in regions with reduced emissions from rice cultivation and wetlands.

Simulation of cloud processing in ECHAM5-HAM

Clouds reflect part of the incoming solar radiation and absorb and emit radiation in the infrared region. They are therefore an important factor in the radiative budget of the Earth, but their influence is susceptible to anthropogenic emissions of aerosol and aerosol precursors. The aerosol abundance in the atmosphere influences cloud optical properties, but chemical processes occurring in the cloud water also affect the aerosol size distribution and chemical composition in return. The later process is referred to the cloud processing of aerosols. The efficiency of the processing is determined by cloud dynamics as well as the size and chemical characteristics of the aerosol population. The research presented here focuses on the mutual influence between aerosol and clouds and the development of parameterizations to represent these processes in large scale models.

The coupled aerosol-climate model ECHAM5-HAM consists of the general circulation model ECHAM version 5 in which an aerosol module (HAM) is implemented that accounts for emissions of aerosol and aerosol precursors, chemical transformations, nucleation of new particles and condensation of semi-volatile H_2SO_4 on existing particles, coalescence between particles and dry and wet deposition. The aerosol population is represented by four soluble and three insoluble aerosol modes, containing (mixtures of) sulfate, organic carbon, black carbon, sea salt and dust.

The model contains a detailed parameterization for cloud processing that predicts the cloud drop number concentration (CDNC) based on simulated aerosol properties and meteorological conditions, and calculates in-cloud sulfur chemistry while accounting for size and chemical differences between cloud drops. The cloud processing parameterization is linked to the climate model's large-scale cloud scheme, which has prognostic equations for cloud liquid water and ice. For our study only the liquid phase is relevant. Four years were simulated in the T21 resolution (approximately 5.6° x 5.6° with a 2400 second time step). The model uses 19 vertical layers in a hybrid s-p- coordinate system, from the surface to 10 hPa. The simulated meteorology is generated by the climate model and does not reflect actual meteorological events.

Figure 3 shows the annually averaged CDNC of the simulated clouds. The distribution is obtained by sampling the model domain as from a satellite, i.e., using the highest cloudy grid box from each model column, but at altitudes below 500 hPa and with a cloud cover larger than 10%. The simulated annual CDNC is between 100 and 450 cm^{-3} (ambient air pressure) in relatively polluted continental air and outflow regions. Simulated cloud drop radii over the continents are of the same range as those obtained from remote sensing measurements. In oceanic regions the simulated CDNC is 5-25 cm^{-3}, significantly smaller than observed. As a result, cloud drop radii in the marine atmosphere are strongly overestimated. The discrepancy is probably due to the fact that organic emissions from the ocean surface are not considered in the model. The potential influence of ocean organics on the chemical composition and the cloud forming properties of marine aerosol is currently being investigated further.

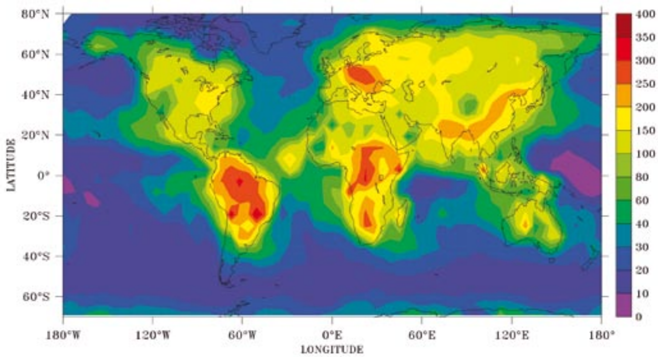


Figure 3
Global distribution of annually averaged CDNC (cm^{-3}). CDNC is sampled as from a satellite, using the highest cloudy grid box below 500 hPa from each model column.

3.4 Atmospheric Dynamics and Boundary Layer Meteorology

The Atmospheric Dynamics and Boundary Layer Meteorology Group is concerned with a relatively wide range of topics. First, due to connections with the Ice and Climate Group, part of the research is concerned with the dynamics of katabatic flow over (melting) glaciers and ice sheets. This is very important for the understanding and quantification of the energy exchange between ice and atmosphere, which ultimately determines the fate of the glacier or ice sheet. Second, since approximately 1995 a research project within this group has been concerned with the synoptic setting and prediction of thunderstorms. This is a very popular topic for Masters thesis research projects. In recent years three articles have been published in peer-reviewed journals by Masters students on this topic. The third research topic is concerned with cyclogenesis, both near the Earth's surface and in the tropopause-break region. In 2006 this has resulted in a PhD thesis on the fundamental theory of cyclogenesis. The fourth topic that is studied by the group is the atmospheric large scale circulation over the poles. Of special interest here is the radiative-chemical-dynamical response of the atmosphere to man-induced changes in the composition of the stratosphere. In the following we give more details of the 4 separate projects.

Large Eddy Simulation of Katabatic Flows

In alpine areas, the heating and cooling of air, in combination with sloping terrain, generate convective valley winds and down slope flows over melting glaciers and ice sheets (katabatic winds), which determine the water supply in lower regions, e.g., relevant for hydro power control and irrigation. In the past, many analytical and computational studies of these flows have left some questions, the first mostly because of the necessary simplifications and the latter because of their lack of resolution of the flow structure and the topography in the domain. This situation has vastly improved and we are now able to perform computations of fairly detailed structures of density driven flows in a complex environment. Supported by recent and planned field and laboratory experiments in idealized topography, these studies provide a better description and understanding of mesoscale weather phenomena in complex terrain.

Present day computers allow the numerical simulation of slope flows by means of a Large Eddy Simulation (LES) model of the Navier-Stokes equations. LES has proven to be a powerful tool in atmospheric boundary layer (ABL) studies and is able to faithfully reproduce the (thermo) dynamic structure of the ABL.

A version of the IMAU LES model has been adapted to simulate flow over tilted terrain, where the acceleration of gravity has a non-zero component in the direction parallel to the ground surface. This requires the reformulation of the model equations in a tilted frame of reference. Moreover, since katabatic flows are found in the stably stratified ABL, which suppresses large-scale turbulence, the numerical resolution has to be fine.

As a first step, we simulated katabatic winds along an 'infinitely' long hill. Figure 1 shows model results of the down-slope wind and temperature. The simulation uses a slope angle of 6 degrees, and a slightly stable background stratification of -5 ˚C/km. The figure shows that the katabatic flow region is very stably stratified, the temperature increases with ~ 4 degrees over 10 m. The wind velocity has a maximum of 6 m/s at an elevation of ~ 5m.

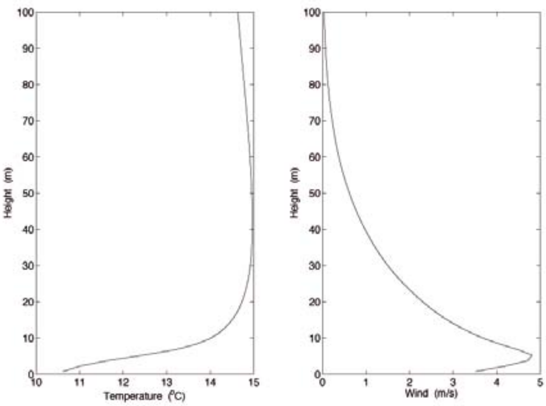


Figure 1
Left:.Temperature (degrees Celcius) as a function of height. Right: down-slope wind velocity (m/s) as function of height (m). Simulation for a slope angle of 6 degrees and background stratification of -5°C/km.

Figure 2 shows a simple laboratory experiment. A water tank was filled with fresh water and then slightly tilted. At the top most end in a small compartment, salt was added to make the fluid heavier. We added also dye to the salty water for visualization purposes. After gently removing the interface between the compartment and the rest of the tank a shallow, turbulent flow developed.

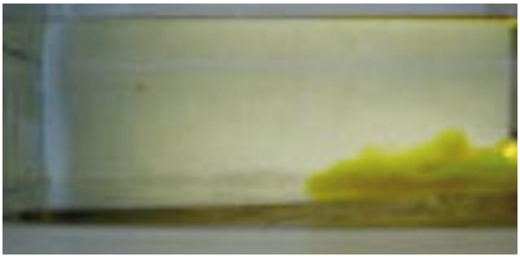


Figure 2
Water tank demonstration of katabatic flow. At the right, salt has been added to the water to generate a density difference, which drives the flow. The shallow, turbulent flow was visualized by adding dye.

Dynamics of synoptic-scale cyclones

The normal-mode stability properties of various extensions of the Eady-, Charney- and Green-models have been investigated in many papers. What was lacking, is a detailed investigation of the non-modal growth properties and the optimal perturbation evolution. Non-modal growth is defined as temporal or sustained growth resulting from the superposition of more than one normal mode. Optimal perturbations are defined as disturbances which amplify optimally for finite-time according to a chosen norm. The idea of non-modal growth is old and goes back at least to the work of Orr (1907). Mainly since the work of Farrell, it has been realized that transient non-modal growth can play an important role in the initial development of perturbations. This has resulted in a substantial literature on the subject in which authors have investigated non-modal, and finite-time optimal growth using both numerical and analytical methods.

A detailed investigation of the different growth mechanisms for the semi-infinite Eady model was made. In this model the baroclinic instability mechanism is absent. It was found that the finite-time optimal growth at the surface could be explained to a large extent by the occurrence of resonance between interior PV and the boundary edge wave at the surface. The growth due to resonance is linear in time. Therefore the resonance effect may be more rapid initially than exponential growth from standard baroclinic instability. Nevertheless the resonance effect has so far not received much attention in the literature.

In a follow up study it was investigated whether the resonance mechanism is also important for the surface development in the presence of exponentially growing normal modes. A detailed investigation was performed of the role of the different growth mechanisms (resonance, PV unshielding (which is a constructive interference of the non-orthogonal NMs) and normal-mode baroclinic instability) in the evolution of optimal perturbations constructed for a two-layer Eady f-plane model. The two-layer Eady model is obtained by replacing the conventional upper rigid lid by a simple but realistic stratosphere. The linear dynamics is described in terms of a variable number of potential vorticity building blocks (PVB's), which are zonally wavelike, vertically localized sheets of potential vorticity. If the optimal perturbation is composed of only one PVB, the rapid surface cyclogenesis can be attributed to the growth of the surface PVB (the edge wave), which is excited by the tropospheric PVB via the resonance effect. If the optimal perturbation is constructed using multiple PVB's, this simple picture is modified only in the sense that PV unshielding dominates the surface amplification for a short time after initialization. The unshielding mechanism rapidly creates large streamfunction values at the surface, as a result of which the resonance effect is much stronger. The influence of the stratosphere to the surface development is negligible. In all cases, the growth due to traditional normal-mode baroclinic instability contributes only little to the surface development up to the optimization time of two days. It takes at least four days for the flow to become fully dominated by normal-mode growth, thereby confirming that finite-time optimal perturbation growth differs in many aspects fundamentally from asymptotic normal-mode baroclinic instability. Finally optimal perturbations were constructed for a two-layer β-plane extension of the Eady model. The optimal perturbations were constructed allowing only one PVB, three PVB's and finally a discrete equivalent of a continuum of PVB's to be present initially. On the f-plane only the PVB at the surface and at the tropopause can be amplified. In the presence of β however, PVB's influence each others growth and propagation at all levels. Compared to the two-layer f-plane model, the inclusion of β slightly reduces the surface growth and propagation speed of all optimal perturbations. Responsible for the reduction are the interior PVB's, which are excited by the initial PVB after initialization. If the optimal perturbation is composed of more than one PVB, the PV unshielding-mechanism dominates the initial amplification in the entire troposphere. At low levels, the interaction between the surface PVB and the interior tropospheric PVB's (in particular those near the steering level) takes over after about half a day, whereas the interaction between the tropopause PVB and the interior PVB's is responsible for the main amplification in the upper-troposphere. Finally, it takes more time, compared to the f-plane model, for the optimal perturbation to settle into the growing normal-mode configuration.

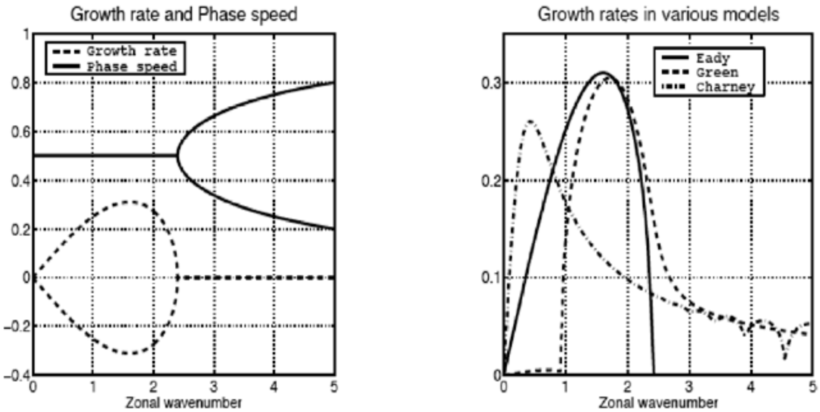


Figure 3

a) The dispersion relation for the discrete NMs in the classic Eady model. A pair of growing and decaying NMs exists for waves longer than the short wave cut-off. For larger wave numbers, the two NMs are neutral and they resemble the boundary edge waves as the wave number increases.

b) Growth rates for two other prototype models: the Charney (1947) model and the Green (1960) model which is the Eady model on the β-plane. In both β-plane models the short wave cut-off is absent.

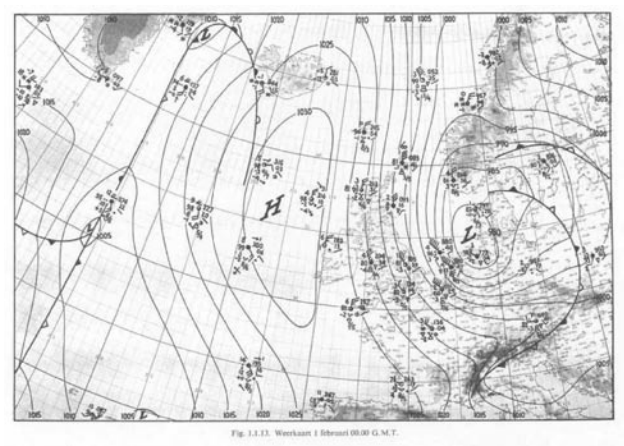


Figure 4

Hand analysis of the famous February 1953 storm that caused enormous devastation in the Netherlands. Large parts in the South-Western part were flooded.

Synoptic setting and forecasting of thunderstorms

So-called Thunderstorm indices, such as the Lifted Index or CAPE, are used weather forecasters as, admittedly, imperfect thunderstorm predictors. During the past years we have continued our search for a better performing thunderstorm predictor. Using an extensive data set comprising locations and times of lightning-strikes during a period of approximately 10 years and high-resolution radiosonde observations made at De Bilt, we found that the surface based lifted index is the best existing index for forecasting the occurrence of thunderstorms. When the surface based lifted index<-3°C there is a 60% chance of thunderstorm occurrence. We think that the reason for this still relatively low probability is due to the neglect of the effect of lifting and replenishing of moisture in the area of interest. These effects can be quantified by the vertically integrated moisture flux convergence. This quantity can be calculated from ECMWF-analyses. We have evaluated the performance of the vertically integrated moisture flux convergence as a thunderstorm predictor, together with the traditional thunderstorm predictors and have come up with a better performing thunderstorm predictor which takes into account both the low level static latent instability and the lifting and replenishing of moisture.

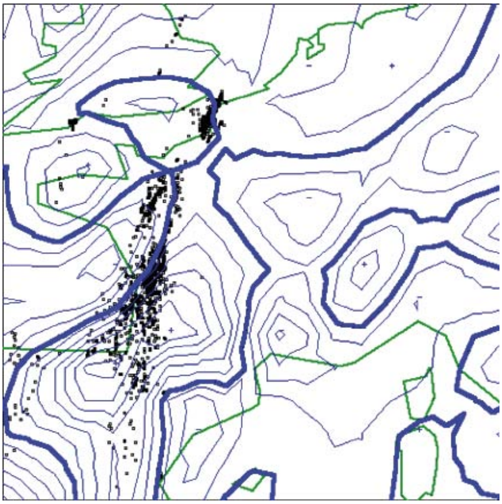


Figure 5
Relation between moisture flux convergence and thunderstorms. Distribution of vertically integrated moisture flux convergence (blue) (zero-contour: thick; contour interval 10^{-4} kg $m^{-2}s^{-1}$) on August 8, 1992, 12 UTC and the location of lightning discharges (black dots) between 12 and 18 UTC fixed by the ATD lightning location system.

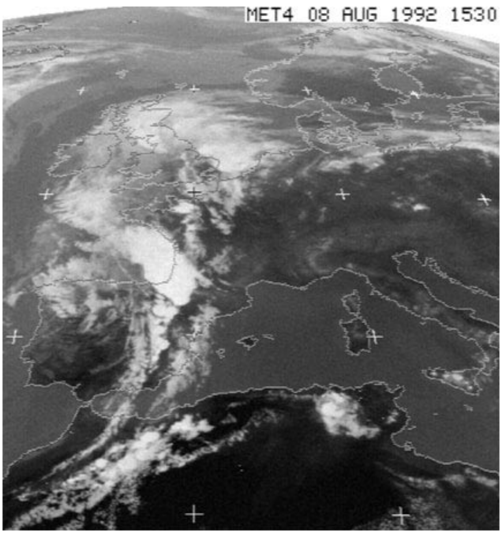


Figure 6
Thunderstormformation due to moisture flux convergence at a front. Meteosat satellite image (infrared channel), on August 8, 1992, 1530 UTC, showing thunderstorms over Western Europe, associated with positive moisture flux convergence and strong potential instability.

Atmospheric General Circulation and Global Change

This project is concerned with the relation between human induced changes to the chemical composition of the atmosphere and the radiative-dynamical response of the atmosphere, in particular concerning the intensity of the stratospheric polar vortex and its influence on the mid-latitude winter circulation near the Earth's surface. The relation between radiative heat sources in the stratosphere and the intensity of the polar vortex can best be understood in terms of potential vorticity. From ERA-40 reanalysis data we find a clear correlation between stratospheric potential vorticity over the winter pole and the westerly component of the wind.

We are investigating the following specific question. Is the observed temperature-increase at the Earth's surface in winter in Western Europe related to changes occurring in the potential vorticity distribution in the stratosphere over the North pole due to more greenhouse gases in the stratosphere and reduced absorption of solar radiation due to reduced ozone concentrations?

3.5 Physical Geography and Oceanography of the Coastal Zone

Research in this theme focuses on the dynamics of sedimentary coastal systems, which include shallow shelf seas, the nearshore zone and estuaries (the transition areas between seas and rivers). These systems are characterized by strong feedbacks between the water motion (driven by wind, tides and density gradients), the transport and distribution of sediment and morphological pattern formation (sand bars, deltas, mudbanks). Field data show that the behaviour of coastal systems is highly sensitive to changes in exogenous conditions (sea level, storm statistics) and anthropogenic activities.

The overall objective of the IMAU coastal research group is to gain more fundamental knowledge about the hydrodynamic and morphologic behaviour of sedimentary coastal systems. The methods employed comprise the collection and analysis of new field data, the development and analysis of process-oriented idealised and complex numerical models, as well as the implementation and application of Data-Model Integration (DMI) techniques. During the period 2005-2006 research efforts were aiming at the understanding of the morphologic development of beaches, surfzones and offshore located shoreface-connected sand ridges and of estuarine and deltaic systems.

Nearshore zone

The research effort on the morphodynamic evolution of the beach and surfzone was based on the ARGUS video research programme and on process-based numerical simulations, the latter funded through the NWO-VIDI grant for Ruessink for a project on Data-Model Integration. The video work focused on the extraction and subsequent analysis of morphological patterns, predominantly sand bars in the intertidal and subtidal domain. We designed an object-oriented approach which separates the Red-Green-Blue content of a low-tide image to the classes 'dry sand', 'wet sand', and 'water' (Figure 1). Our approach is a major improvement relative to previous studies, which classified images on a pixel level, disregarding the spatially coherent structure inherent to the images. Subsequent analysis of the 'dry sand' class at Noordwijk beach showed that the intertidal sandbars are generated close to the low-water line, migrate slowly onshore, and are finally destroyed during prolonged periods of high waves and storm surges. A major benefit of the ARGUS programme is its long-term character relative to the time scale inherent to nearshore morphology. We used this aspect particularly for the Argus station at the Gold Coast (Australia), from which a 7-year long dataset of daily subtidal sand bar position and alongshore variability was quantified in collaboration with the Water Research Laboratory of the University of New South Wales. This data set is presently being analyzed with a number of data-driven auto-regressive models, including recurrent neural networks.

In collaboration with the Marine Research Institute (ICM-CMIMA-CSIC) and the Politechnical University of Catalunya (UPC), both located in Barcelona (Spain), we investigated the dynamics of shore-attached oblique sand bars, which are frequently detected by the ARGUS video cameras in the Noordwijk subtidal area. An extensive data analysis was carried out, which revealed important information of the characteristics and dynamics of these bars. It was found that the wave length of the bar patches ranged from 21 to 75 m and their mean celerity was 4.9 m/day in the direction of the longshore current (they migrated at rates up to 26 m/day). Bars had an orientation either perpendicular or oblique with respect to the shoreline. In the latter case, they deviated against the longshore current (up-current orientation). Bars persisted during periods from 1 day to 2 months, coexisting with regular waves of intermediate heights and large angles of incidence with respect to the shore-normal. The underlying large-scale bathymetry also affected bar formation: certain inner surf zone slopes and inner bar troughs were more conductive to growth. Besides, it was investigated whether the initial formation of these bars could be simulated with a morphodynamic model. The results indicated that the predicted shape (including the wave length) and growth rate were in agreement with observations but the model overestimated the migration rate. The key aspect to obtain up-current oriented bars was the assumption that the suspended sediment concentration is relatively constant throughout the inner surf zone.

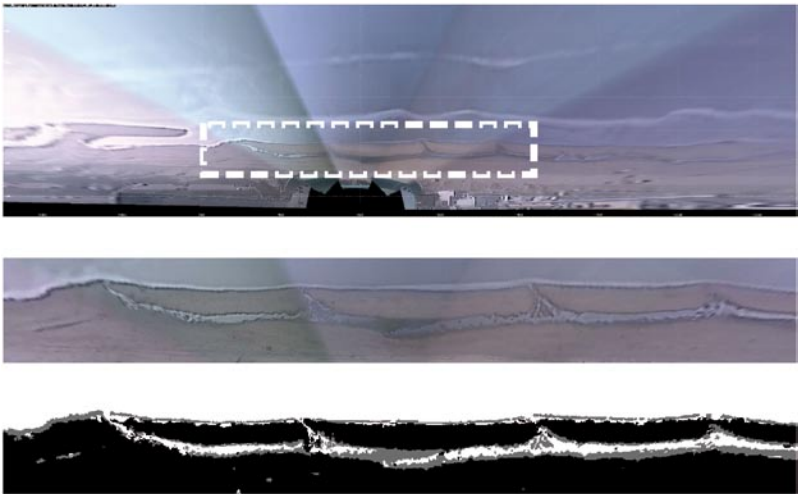


Figure 1
Top panel: plan view of the intertidal and subtidal zone at Noordwijk, Netherlands. The brown part at the bottom of this panel is the beach, characterised by an intertidal bar, separated from the supratidal dry beach by a trough and interseted by cross-shore oriented rip channels. Middle panel: detail of the top panel. Bottom panel: classified image (Quartel et al., 2006), where black is dry sand (supratidal beach and intertidal sand bars), grey is wet sand (troughs and waterline), and white is water (sea, troughs and rips).

In addition to these ARGUS data-based studies, we built a wave-averaged, cross-shore profile model that aims to predict the on/offshore migration of subtidal sand bars under time-varying wave forcing. In collaboration with WL|Delft Hydraulics, the Technical University of Delft, UNESCO-IHE and the Japanese Port and Airport Research Institute (PARI), this model was tested successfully against a number of data sets. The model is currently being used to examine the predictability of nearshore morphology (how far into the future can we make sensible predictions?) and to explore why subtidal sandbars often behave in a periodic offshore directed manner without a periodic boundary forcing.

Shoreface-connected sand ridges

These bedforms are observed on sandy coastal shelves where storms frequently occur. They are 3-6 km spaced apart, have heights of several metres (in mean depths of 10-20 m), migrate about 10 m per year in the direction of storm-driven alongshore currents and they have an angle with the coastline of 20 -50°. The finest (coarsest) sediment is found on the seaward (landward) sides of the ridges. Previous models showed that these ridges can form due to inherent feedbacks between waves, the storm-driven currents and the sandy bottom. However, the effect of waves was included in a parametric manner and feedbacks between the ridges and the waves were not accounted for. A new wave module was developed (joint work with

UPC Barcelona) and its effect on the dynamics of bedforms was investigated. It was found that feedbacks between sand ridges and waves cause additional stirring of sediment at the upstream sides of the ridges. This mechanism significantly enhances the growth and migration of the ridges (see Figure 2). Model results are in fair agreement with field data.

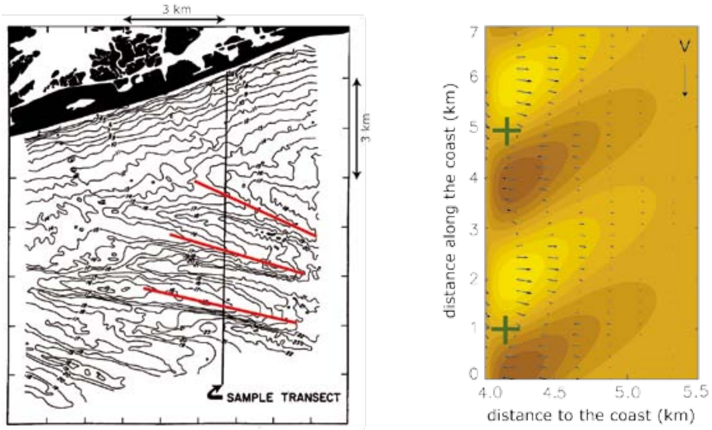


Figure 2.

Left: bathymetry of Long Island inner shelf, contour lines each 1 m; red lines indicate shoreface-connected sand ridges.

Right: modelled sand ridges (brown/yellow represent crest/trough areas). Arrows indicate perturbations in the wave direction induced by the ridges. The thick arrow shows the direction of the storm-driven current. In areas where wave rays converge additional erosion of sand occurs (Vis-Star et al., 2007).

Deltaic and estuarine systems

The national programme 'Dynamics of outer deltas', funded by NWO-ALW and coordinated by the IMAU, ended in 2006. It allowed scientists from different Dutch institutions to work together with the aim to understand the presence and variability of these sandy morphologic structures. The efforts resulted in important breakthroughs, of which several are reported in the PhD thesis of M. van der Vegt (March 2006). His research demonstrates how the integration of process-based idealised and complex models can be employed to systematically unravel the complex dynamics of sandy barrier coasts and outer deltas.

Estuarine studies focused on four estuaries, viz. James River estuary, Upper Chesapeake Bay (both at east US coast), the Ems estuary (situated at the Dutch-German border) and the Berau estuary and adjacent delta (Kalimantan, Indonesia). A cross-sectional model was developed and analysed to explain the observed lateral distribution of tidal currents, residual currents and entrapment of fine sediment in the first two estuaries. In joint collaboration with A. Valle Levinson (Univ. of Florida) and C.T. Friedrichs (Virginia Institute of Marine Science) it was demonstrated that model results compare well with field observations (see Figure 3). The trapping of sediment is largely controlled by density currents caused by lateral salinity gradients.

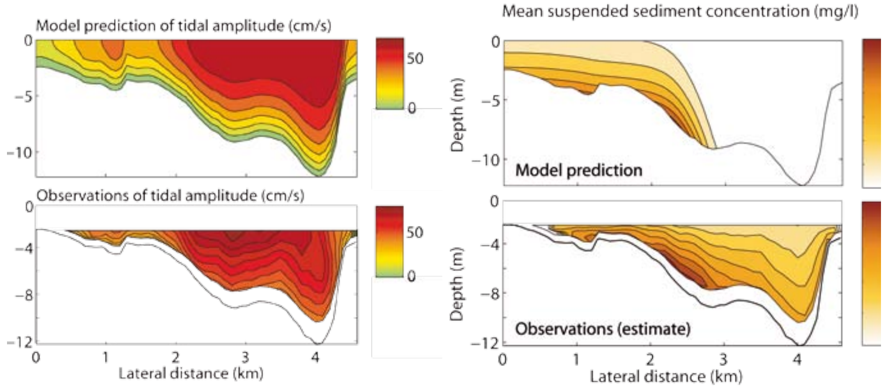


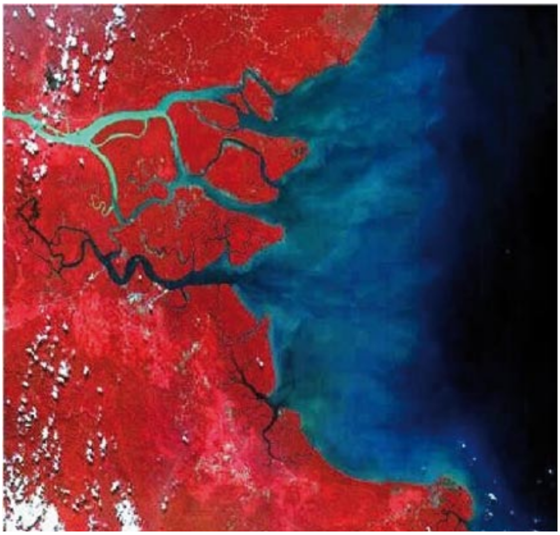
Figure 3.
Modelled and observed lateral distribution of tidal current amplitude (left) and tidally averaged suspended sediment concentration in a cross-section of James River estuary (Huijts et al., 2006).

In 2005-2006 IMAU researchers initiated and participated in ten cruises into the Ems estuary. This was done in the framework of a project 'Dynamics of estuarine turbidity maxima, coupling between physical and biological processes', which involves close collaboration with RU Groningen, Rijkswaterstaat and two German agencies in Emden (Niedersachsen Ports and the Wasser und Schifffahrts Amt). These cruises, which involved measurements both along longitudinal and lateral transects, provided important new field data of currents, density structure, suspended sediment concentrations (SSC) and biological parameters. The data showed that, during a period of 20 years of intense dredging activities, the SSC have increased by a factor of 5 and the location of the estuarine turbidity maximum (ETM) has shifted ±20 km upstream. Moreover, the SSC distribution is highly asymmetrical (steep on the upstream side of the ETM, mild on its downstream side), a maximum in fluorescence occurs downstream of the ETM and in the cross-sections the suspended sediment is trapped near the northern bank. To explain these phenomena several model studies were performed. A new along-estuary model, which computes currents and SSC distribution, shows the large effects of deepening the estuary on the ETM dynamics. The asymmetry in the distribution of SSC near its peak is due to turbidity currents. The location of the fluorescence maximum is the result of the fact that the growth of phytoplankton is limited by light (effective near and landward of the ETM) and by nutrients (effective near the seaward boundary). The observed lateral distribution of SSC turned out to be significantly influenced by flocculation of sediment during slack tide.

In 2005 NWO-WOTRO started funding a research cluster, including 7 different PhD and post-doc projects with the name "From River Basin to Barrier Reef". This research cluster will carry out physical, biological, marine-geological and socio-economic research in the coastal waters of North East Kalimantan, Indonesia (Figure 4). IMAU is leading partner in the cluster and is responsible for two PhD projects, which involve cooperation with the Royal NIOZ, ITC, ITB

Bandun, and LIPLI-LON Jakarta. The first PhD project deals with soil erosion and sediment supply and focuses on the effect of estuarine mixing processes – in relation to river discharges and tidal conditions – on the seaward transfer of water and sediment. The second project aims to establish and understand the mixing and dispersal processes determinative to corals in the Berau Barrier reef system.
Initial modelling and surveying in the coastal waters started in the autumn of 2006 and will continue in 2007. Preliminary results of the pilot campaign in 2003 clearly indicate the presence of a zonation in the coastal zone in terms of sediment load and sediment properties. Estuarine turbidity maxima were observed in two separate branches of the Berau system and are presently subject of ongoing studies.

Figure 4.
The Berau river basin and delta with two northern estuarine branches (light color in river due to suspended matter; coast both shallow and turbid water) and a tide-dominated southern branch.



4. Awards & Honours

EGU Lewis Fry Richardson Medallist 2005 - Prof.dr.ir. H.A. Dijkstra

Member of the South African Academy for Science and Art - Prof.dr. W.P.M. de Ruijter

Honorary member scientific committee ITM (NATO CCMS) - Dr. H. van Dop

NWO-VENI grant (2006) - dr. A. v.d. Heydt

NWO-VICI grant (2006) - prof.dr. T. Röckmann

5. Publications

Books

Dijkstra, H.A.,

Nonlinear Physical Oceanography, A dynamical Systems Approach to the Large Scale Ocean Circulation and El Niño

2nd Revised and Enlarged Edition Series: Atmospheric and Oceanographic Sciences Library, vol 28, Springer, The Netherlands

Van Rijn, L.C., Soulsby, R.L., Hoekstra, P. and Davies, A.G.,

SANDPIT. Sand Transport and Morphology of Offshore Sand Mining Pits. Process knowledge and guidelines for coastal management (EU 5th framework programme).

Aqua Publications, The Netherlands

Van Rijn, L.C.,

Principles of sediment transport in rivers, estuaries and coastal seas, part II supplement.

Aqua Publications, The Netherlands

Reviewed scientific publications

	2005	2006	Total
Only IMAU author(s)	25	18	43
First author IMAU + foreign author(s)	9	8	17
First author foreign + IMAU	18	20	38
First author IMAU + other Dutch	6	8	14
First author Dutch + IMAU	6	9	15
Total	**64**	**63**	**127**

2005

Aagaard, T., A. Kroon, S. Andersen, R. Moller Sorensen, S. Quartel, N. Vinther - Intertidal beach change during storm conditions, Egmond, The Netherlands - Marine Geology 218, 65-80, 2005

Aarninkhof, S.G.J., B.G. Ruessink, J.A. Roelvink - Nearshore subtidal bathymetry from time-exposure video images - Journal of Geophysical Research 110, C06011, doi:10.1029/2004JC002791, 2005

Bamber, J.L., W. Krabill, V. Raper, J.A. Dowdeswell, J. Oerlemans- Elevation changes measured on Svalbard glaciers and ice caps from airborne laser data - Annals of Glaciology 42, 202-208 2005

Bergamaschi, P., M.C. Krol, F. Dentener, A. Vermeulen, F. Meinhardt, R. Graul, M. Ramonet, W. Peters, E.J. Dlugokencky - Inverse modelling of national and European CH_4 emissions using the atmospheric zoom model TM5- Atmospheric Chemistry and Physics Discussions 5(1), 1007-1066, 2005

Bintanja, R., R.S.W. van de Wal, J. Oerlemans - Modelled atmospheric temperatures and global sea levels over the past million years - Nature 437, 125-128, doi:10.1038/nature03975, 2005

Bintanja, R., R.S.W. van de Wal, J. Oerlemans - A new method to estimate ice age temperatures - Climate Dynamics 24, 197-211, 2005

Bourgamont, M., J.L. Bamber, W. Greuell - A surface mass balance model for the Greenland ice sheet - Journal of Geophysical Research 110(F4), 10.1029/ 2005JF000348, 2005

Brasseur, P., P. Bahurel, L. Bertino, F. Birol, J.-M. Brankart, N. Ferry, S. Losa, E. Remy, J. Schroeter, S. Skachko, C.-e. Testut, B. Tranchant, J. Verron, P.J. van Leeuwen - Data assimilation in the MERCATOR and MERSEA operational ocean forecasting systems - Quaterly Journal of the Royal Meteorological Society 131, 3561-3582, 2005

Calluy, G.H.K., H. Bjornssen, W. Greuell, J. Oerlemans - Estimating the mass balance of Vatnajokull from NOAA-AVHRR imagery - Annals of Glaciology 42, 118-124, 2005

De Laat, A.T.J., I. Aben, G.-J. Roelofs - A model perspective on total tropospheric O_3 column variability and implications for satellite observations - Journal of Geophysical Research 110, 10.1029/2004JD005264, 2005

De Ruijter, W.P.M., H. Ridderinkhof, M.W. Schouten - Variability of the southwest Indian Ocean - Philosophical Transactions of the Royal Society of London (A) 363, 63-76, doi:10.1098/rsta.2004.1478, 2005

De Vries, H., J.D. Opsteegh - Optimal perturbations in the eady model: resonance versus PV unshielding - Journal of the Atmospheric Sciences 62, 492-505, 2005

Drijfhout, S.S., J. Donners, W.P.M. de Ruijter - The origin of intermediate and subpolar mode waters crossing the Atlantic equator in OCCAM - Geophysical Research Letters 32, doi:10.1029/2004GL021851, 2005

Dijkstra, H.A., W. Weijer - Stability of the global ocean circulation: basic bifurcation diagrams - Journal of Physical Oceanography 35, 933-948, 2005

Dijkstra, H.A., M. Ghil - Low-frequency variability of the ocean circulation: a dynamical systems approach - Reviews of Geophysics 43, RG3002, doi:10.1029/ 2002RG000122, 2005

Greuell, W., J. Oerlemans - Validation of AVHRR- and MODIS-derived albedos of snow and ice surfaces by means of helicopter measurements - Journal of Glaciology 51 (172), 37-48, 2005

Greuell, W.J., J. Oerlemans - Assessment of the surface mass balance along the K-transect (Greenland ice sheet) from satellite-derived albedos - Annals of Glaciology 42, 107-117, 2005

Gruais, I., N. Rittemard, H.A. Dijkstra - A priori estimations of a global homotopy residue continuation method - Nonlinear Functional Analysis and Optimization 26 (4-5), 507-521, 2005

Grunnet, N.M., B.G. Ruessink - Morphodynamic response of nearshore bars to a shoreface nourishment - Coastal Engineering 52, 119-137, 2005

Grunnet, N.M., B.G. Ruessink, D.J.R. Walstra - The influence of tides,wind and waves on the redistribution of nourished sediment, Terschelling, the Netherlands - Coastal Engineering 52, 617-631, 2005

Helsen, M.M., R.S.W. van de Wal, M.R. van den Broeke, E.R.T. Kerstel, V. Masson-Delmotte, H.A.J. Meijer, C.H. Reijmer, M.P. Scheele - Modelling the isotope composition of snow using backward trajectories: a particular precipitation event in Dronning Maud Land, Antarctica - Annals of Glaciology 39, 293-299, 2005

Helsen, M.M., R.S.W van de Wal, M.R. van den Broeke, D. van As, H.A.J Meijer, C. H. Reijmer - Oxygen isotope variability in snow from western Dronning Maud Land, Antarctica and its relation to temperature - Tellus 57B(5), 423-435, 2005

Hoitink, A.J.F., P. Hoekstra - Observations of suspended sediment from ADCP and OBS measurements in a mud-dominated environment - Coastal Engineering 52, 103-118, 2005

Houweling, S., W. Hartmann, I. Aben, H. Schrijver, J. Skidmore, G.-J. Roelofs, F.-M. Breon - Evidence of systematic errors in SCIAMACHY-observed CO_2 due to aerosols - Atmospheric Chemistry and Physics 5, 3003-3013, 2005

Isaksson, E., J. Kohler, V. Pohjola , J. Moore, M. Igarashi, L. Karlöf, T. Martma, H.A.J. Meijer, H. Motoyama, H. Vaikmae , R.S.W. van de Wal - Two ice core d18O records from Svalbard illustrating climate and sea ice variability over the last 400 years - The Holocene 15(4), 501-509, 2005

Kaczmarska, M., E. Isaksson, L. Karlöf, J-G. Winther, J. Kohler, F. Godtliebsen, L. Ringstad Olsen, C. M. Hofstede, M.R. van den Broeke, R.S.W. van de Wal, N. Gundestrup - Accumulation variability derived from an ice core from coastal Dronning Maud Land, Antarctica - Annals of Glaciology 39, 339-345, 2005

Karlöf, L., E. Isaksson, J.-G. Winther, N. Gundestrup, H.A.J. Meijer, R. Mulvaney, M. Pourchet, C. Hofstede, M. Kacmarska, G. Lappegaard, R. Petterson, M.R. van den Broeke, R.S.W. van de Wal - Accumulation variability over a small area in east Dronning Maud Land, Antarctica, as determined from shallow firn cores and snow pits: some implications for ice core records - Journal of Glaciology 51(174), 343-352, 2005

Kekonen, T., J. Moore, P. Perämäki, R. Mulvaney, E. Isaksson, V. Pohjola, R.S.W van de Wal - A complete ion record of the Lomonosovfonna ice core, Svalbard providing environmental and climate information for the past 800 years - Journal of Geophysical Research 110, D07304, doi:10.1029/2204JD005223, 2005

Keppler, F., D.B. Harper, T. Röckmann, R.M. Moore, J.T.G. Hamilton - New insight into the atmospheric chloromethane budget gained using stable carbon isotope ratios - Atmospheric Chemistry and Physics 5, 2403-2411, SRef-ID: 1680-7324/acp/2005-5-2403, 2005

Kleinhans, M.G. - Review of “Science, philosophy and physical geography by Rob Inkpen” - arth-Science Reviews 70, 313-314, 2005

Kleinhans, M. G. - Autogenic cyclicity of foreset sorting in experimental Gilbert-type deltas - Sedimentary Geology 181, 215-224, doi:10.1016/j.sedgeo.2005.09.001, 2005

Kleinhans, M. G. - Upstream sediment input effects on experimental dune trough scour in sediment mixture - Journal of Geophysical Research 110, F04S06, doi:10.1029/2004JF000169, 2005

Kleinhans, M. G. - Grain-size sorting in grain flows at the lee-side of deltas - Sedimentology 52, 291-311, doi: 10.1111/j.1365-3091.2005.00698.x, 2005

Klok, E.J., M. Nolan, M.R. van den Broeke - Analysis of meteorological data and the surface energy balance of McCall Glacier, Alaska, USA - Journal of Glaciology 51(174), 451-461, 2005

Lefebre, F., X. Fettweis, H. Gallée, J.-P. van Ypersele, P. Marbaix, W. Greuell, P. Calanca - Evaluation of a high-resolution regional climate simulation over Greenland - Climate Dynamics 55 (1), 99-116, 2005

Matthes, S., V. Grewe, R. Sausen, G.-J. Roelofs - Global impact of road traffic emissions on tropospheric ozone - Atmospheric Chemistry and Physics Discussions 5(5), 10339-10367, 2005

Oerlemans, J. - Extracting a climate signal from 169 glacier records - Science 308, 675-677, 2005

Oerlemans, J. - Antarctic ice volume for the last 740 ka calculated with a simple ice sheet model - Antarctic Science 17(2), 281-287, 2005

Oerlemans, J., S. Bassford, W. Chapman, J. Dowdeswell, A. Glazovsky, J.-O. Hagen, K. Melvold, M. de Ruijter de Wildt, R.S.W van de Wal - Estimating the contribution of Arctic glaciers to sea level change in the next hundred years - Annals of Glaciology 42, 230-236, 2005

Rattan, S.S.P., B.G. Ruessink, W.W. Hsieh - Non-linear complex principal component analysis of nearshore bathymetry - Nonlinear Processes in Geophysics 12, 661-670, 2005

Reijmer, C.H.,E. van Meijgaard, M.R. van den Broeke - Evaluation of temperature and wind over Antarctica in a regional atmospheric climate model using one year of automatic weather station data and upper air observations - Journal of Geophysical Research 110(D04103), doi:10.1029/2004JD005234, 2005

Rolstad, C., J. Oerlemans - The residual method for determination of the turbulent exchange coëfficient applied to automatic weather station data from Iceland, Switzerland and West Greenland - Annals of Glaciology 42, 356-372, 2005

Ruessink, B.G. - Predictive uncertainty of a nearshore bed evolution model - Continental Shelf Research 25, 1053-1069, 2005

Ruessink, B.G. - Calibration of nearshore process models – application of a hybrid genetic algorithm - Journal of Hydroinformatics 7, 135-149, 2005

Schouten, M.W., H. Ridderinkhof, W.P.M. de Ruijter - A seasonal intrusion of subtropical water in the Mozambique Channel - Geophysical Research Letters 32, doi: 10.1029/2005GL023131, 2005

Simonnet, E., M. Ghil, H.A. Dijkstra - Homoclinic bifurcations in the barotropic quasi-geostrophic double-gyre circulation - Journal of Marine Research 63, 931-956, 2005

Stevens, B., Chin-Hoh Moeng, A.S. Ackerman, C.S. Bretherton, A. Chlond, S.R. de Roode, J. Edwards, J.-C. Golaz, Hongli Jiang, M. Khairoutdinov, M.P. Kirkpatrick, D.C. Lewellen, A. Lock, F. Müller, D.E. Stevens, E. Whelan, Ping Zhu - Evaluation of large-eddy simulations via observations of nocturnal marine stratocumulus - Monthly Weather Review 133 (6), 1443-1462, 2005

Terwisscha van Scheltinga, A., H.A. Dijkstra - Nonlinear data-assimilation using implicit models - Nonlinear Processes in Geophysics 12, 515-525, 2005

Van Aalst, M.K., J. Lelieveld, B. Steil, C. Brühl, P. Jöckel, M.A. Giorgetta, G.-J. Roelofs - Stratospheric temperatures and tracer transport in a nudged 4-year middle atmosphere GCM simulation - Atmospheric Chemistry and Physics Discussions 5, 961-1006, 2005

Van As, D., M.R. van den Broeke, C.H. Reijmer, R.S.W. van de Wal - The summer surface energy balance on the high Antarctic plateau - Boundary-Layer Meteorology 115(2), 289-317, doi 10.1007/s10546-004-4631-1, 2005

Van As, D., M.R van den Broeke, R.S.W van de Wal - The daily cycle of the surface layer and energy balance on the high Antarctic plateau - Antarctic Science 17(1), 121-133, DOI:10.1017/S095410200500252X., 2005

Van de Berg, W.J., M.R. van den Broeke, C.H. Reijmer, E. van Meijgaard - Characteristics of the Antarctic surface mass balance, 1958-2002, using a regional atmospheric climate model - Annals of Glaciology 41, 97-104, 2005

Van den Broeke, M. R., C.H. Reijmer, D. van As, R.S.W. van de Wal, J. Oerlemans - Seasonal cycles of Antarctic surface energy balance from Automatic Weather Stations - Annals of Glaciology 41, 131-139, 2005

Van den Broeke, M.R., C.H. Reijmer, R.S.W. van de Wal - The surface radiation balance in Antarctica as measured with Automatic Weather Stations - Journal of Geophysical Research 109, (D9), D09103 10.1029/2003JD004394, 2005

Van den Broeke, M.R. - Strong melting preceded collapse of Antarctic ice shelf - Geophysical Research Letters 32, doi: 10.129/2005GL023247, 2005

Van den Broeke, M.R., D. van As, C.H. Reijmer, R.S.W. van de Wal - Sensible heat exchange at Antarctic snow surface: a study with automatic weather stations - International Journal of Climatology 25, 1080-1101, 2005

Von der Heydt, A.S., H.A. Dijkstra - Flow reorganizations in the Panama Seaway: A cause for the demise of miocene corals? - Geophysical Research Letters 32, L02609, doi:10.1029/2004GL020990, 2005

Van de Wal, R.S.W., W. Greuell, M.R. van den Broeke, C.H. Reijmer, J. Oerlemans - Surface mass-balance observations and automatic weather station data along a transect near Kangerlussuaq, West Greenland - Annals of Glaciology 42, 311-316, 2005

Van Dop, H., D. van As, A. van Herwijnen, M.F. Hibberd, H. Jonker - Length scales of scalar diffusion in the convective boundary layer: laboratory observations - Boundary-Layer Meteorology 116, 1-35, 2005

Van Dijk, T.A.G.P., M.G. Kleinhans - Processes controlling the dynamics of compound sandwaves in the North Sea, Netherlands - Journal of Geophysical Research 110, doi:10.1029/2004JF000173, 2005

Van Hoof, T.B., K.A. Kaspers, F. Wagner, R.S.W. van de Wal, W.M. Kürschner, H. Visscher - Atmospheric CO_2 during the 13th century AD: reconciliation of data from ice core measurements and stomatal frequency analysis - Tellus 57B, 351-355, 2005

Van Maren, D.S., P. Hoekstra - Dispersal of suspended sediments in the turbid and highly stratified Red River plume - Continental Shelf Research 25, 503-519, 2005

Whitehead, J.A., L.A. te Raa, T. Tozuka, J.B. Keller, K. Bradley - Laboratory observations and simple models of slow oscillations in cooled salt-stratified bodies - Tellus A 57, 798-809, 2005

Zelle, H., G.J. van Oldenborgh, G. Burgers, H.A. Dijkstra - El Nino and Greenhouse warming: results from ensemble simulations with the NCAR CCSM - Journal of Climate 18 (22), 4669–4683, 2005

2006

Bassford, R.P., M.J. Siegert, J.A. Dowdeswell, J. Oerlemans, A.F. Glazovsky, Y.Y. Macheret Quantifying the mass balance of ice caps on Severnaya Zemlya, Russian High Arctic. I: Climate and mass balance of the Vavilov Ice Cap - Arctic- Antarctic and Alpine Research 38 (1), 1-12, 2006

Bernard, S., T. Röckmann, J. Kaiser, J.-M. Barnola, H. Fischer, T. Blunier, J. Chappellaz - Constraints on N_2O budget changes since pre-industrial time from new firn air and ice core isotope measurements - Atmospheric Chemistry and Physics 6, 493-503, SRef-ID: 1680-7324/acp/2006-6-493, 2006

De Laat, A.J.T., A.M.S. Gloudemans, H. Schrijver, M.M.P. van den Broek, J.F. Meirink, I. Aben, M.C. Krol - Quantitative analysis of SCIAMACHY carbon monoxide total column measurements - Geophysical Research Letters 33, doi:10.1029/ 02005GL025530, 2006

De Meij, A., M.C. Krol, F. Dentener, E. Vignati, C. Cuvelier, P. Thunis - The sensitivity of aerosol in Europe to two different emission inventories and temporal distribution of emissions - Atmospheric Chemistry and Physics 6, 4287-4309, 2006

Dentener, F., J. Drevet, J.F. Lamarque, I. Bey, B. Eickhout, A.M. Fiore, D. Hauglustaine, L.W. Horowitz, M.C. Krol, U.C. Kulshrestha, M. Lawrence, C. Galy-Lacaux, S. Rast, D. Shindell, D. Stevenson, T. V. Noije, C. Atherton, N. Bell, D. Bergman, T. Butler, J. Cofala, B. Collins, R. Doherty, K. Ellingsen, J. Galloway, M. Gauss, V. Montanaro, J.F.Müller, G. Pitari, J. Rodriguez, M. Sanderson, S. Strahan, M. Schultz, K. Sudo, S. Szopa, O. Wild - Nitrogen and sulfur deposition on regional and global scales: a multi-model evaluation - Global Biogeochemical Cycles 20, GB4003, doi:4010.1029/ 2005GB002672, 2006

Dentener, F., D. Stevenson, K. Ellingsen, T. van Noije, M. Schultz, M. Amann, C. Atherton, N. Bell, D. Bergmann, I. Bey, L. Bouwman, T. Butler, J. Cofala, B. Collins, J. Drevet, R. Doherty, B. Eickhout, H. Eskes, A. Fiore, M. Gauss, D. Hauglustaine, L. Horowitz, I.S.A. Isaksen, B. Josse, M. Lawrence, M.C. Krol, J.F. Lamarque, V. Montanaro, J.F. Müller, V.H. Peuch, G. Pitari, J. Pyle, S. Rast, J. Rodriguez, M. Sanderson, N.H. Savage, D. Shindell, S. Strahan, S. Szopa, K. Sudo, R.V. Dingenen, O. Wild, G. Zeng - Global atmospheric environment for the next generation - Environmental Science and Technology 40, 3586-3594, DOI: 3510.1021/es0523845, 2006

De Ruijter, W.P.M., G.-J.A. Brummer, S.S. Drijfhout, J.R.E. Lutjeharms, F. Peeters, H. Ridderinkhof, H. van Aken, P.J. van Leeuwen - Observations of the inter-ocean exchange around South Africa - Eos, Transactions 87 (9), 97-101, 2006

De Vries, H., J.D. Opsteegh - Dynamics of singular vectors in the semi-infinite eady model: nonzero ß but zero mean PV gradient - Journal of Atmospheric Sciences 63, 547-564, 2006

Dijkstra, H.A., L. te Raa, M. Schmeits, J. Gerrits - On the physics of the Atlantic multidecadal oscillation - Ocean Dynamics 56, 36-50, 2006

Dijkstra, H.A. - Interaction of SST Modes in the North Atlantic Ocean - Journal of Physical Oceanography 36, 286-299, 2006

Dijkstra, H. A. - The ENSO phenomenon: theory and mechanisms - Advances in Geosciences 6, 3 -15, 2006

EPICA Community Members: C. Barbante, J.-M. Barnola, S. Becagli, J. Beer, M. Bigler, C. Boutron, T. Blunier, E. Castellano, O. Cattani, J. Chappellaz, D. Dahl-Jensen, M. Debret, B. Delmonte, D. Dick, S. Falourd, S. Faria, U. Federer, H. Fischer, J. Freitag, A. Frenzel, D. Fritzsche, F. Fundel, P. Gabrielli, V. Gaspari, R. Gersonde, W. Graf, D. Grigoriev, I. Hamann, M. Hansson, G. Hoffmann, M.A. Hutterli, P. Huybrechts, E. Isaksson, S. Johnsen, J. Jouzel, M. Kaczmarska, T. Karlin, P. Kaufmann, S. Kipfstuhl, M. Kohno, F. Lambert, Anja Lambrecht, Astrid Lambrecht, A. Landais, G. Lawer, M. Leuenberger, G. Littot, L. Loulergue, D. Luethi, V. Maggi, F. Marino, V. Masson-Delmotte, H. Meyer, H. Miller, R. Mulvaney, B. Narcisi, J. Oerlemans, H. Oerter, F. Parrenin, J.-R. Petit, G. Raisbeck, D. Raynaud, R. Roethlisberger, U. Ruth, O. Rybak, M. Severi, J. Schmitt, J. Schwander, U. Siegenthaler, M.-L. Siggaard-Andersen, R. Spahni, J.P. Steffensen, B. Stenni, T.F. Stocker, J.-L. Tison, R. Traversi, R. Udisti, F. Valero-Delgado, M.R. van den Broeke, R.S.W. van de Wal, D. Wagenbach, A. Wegner, K. Weiler, F. Wilhelms, J.-G. Winther, E. Wolf - One-to-one coupling of glacial climate variability in Greenland and Antarctica - Nature 444, 195-198, doi:10.1038/nature05301, 2006

Elfrink, B., D.M. Hanes, B.G. Ruessink - Parameterization and simulation of near bed orbital velocities under irregular waves in shallow water - Coastal Engineering 53, 915-927, 2006

Frankenberg, C., J. F. Meirink, P. Bergamaschi, A. P. H. Goede, M. Heimann, S. Körner, U. Platt, M. van Weele, T. Wagner - Satellite chartography of atmospheric methane from SCIAMACHY on board ENVISAT: Analysis of the years 2003 and 2004 - Journal of Geophysical Research 111, D07303, doi: 10.1029/2005JD006235, 2006

Geerling, G.W., A.M.J. Ragas, R.S.E.W. Leuven, J.H. van den Berg, M. Breedveld, D. Liefhebber, A.J.M. Smits - Succession and rejuvention in floodplains along the River Allier (France) - Hydrobiologia 565, 71-86, 2006

Gloudemans, A.M.S., M.C. Krol, J.F. Meirink, A.T.J. de Laat, G.R. van der Werf, H. Schrijver, M.M.P. van de Broek, I. Aben - Evidence for Long-range transport of Carbon Monoxide in the Southern Hemisphere from SCIAMACHY observations - Geophysical Research Letters 33, L16807, doi:16810.11029/12006GL02680, 2006

Helsen, M.M., R.S.W. van de Wal, M.R. van den Broeke, V. Masson-Delmott, H.A.J. Meijer, M.P. Scheele, M. Werner - Modeling the isotopic composition of Antarctic snow using backward trajectories: simulation of snow pit records - Journal of Geophysical Research 111 (D15109), doi: 10.1029/2005JD006524, 2006

Hesselink, A. W., M.G. Kleinhans, G.L. Boreel - Historic discharge measurements in three Rhine branches - Journal of Hydraulic Engineering 132, 140-145, doi:10.1061/ (ASCE)0733-9429(2006)132:2(140), 2006

Hoitink, A.J.F., P. Hoekstra, D.S. van Maren - Comment on "On the role of diurnal tides in contributing to asymmetries in tidal probability distribution functions in areas of predominantly semi-diurnal tide" by P.L. Woodworth, D.L. Blackman, D.T. Pugh and J.M. Vassie (in Estuarine, - Coastal and Shelf Science 64, (2005), 235-240), Estuarine, Coastal and Shelf Science 67, 340-341, 2006

Houweling, S., T. Röckmann, I. Aben, F. Keppler, M.C. Krol, J.F. Meirink, E.J. Dlugokencky, C. Frankenberg - Atmospheric constraints on global emissions of methane from plants - Geophysical Research Letters 33 (L15821), doi:10.1029/ 2006GL026162, 2006

Huijts, K.M.H., H.M. Schuttelaars, H.E. de Swart, A. Valle-Levinson - Lateral entrapment of sediment in tidal estuaries: An idealized model study - Journal of Geophysical Research 111, C12016, doi: 10.1029/2006JC003615, 2006

Kaczmarska, M., E. Isaksson, L. Karlöf, O. Brandt, J.-G. Winther, R.S.W van de Wal, M.R. van den Broeke, S.J. Johnsen - Ice core melt features in relation to Antarctic coastal climate - Antarctic Science 18(2), 271-278, 2006

Keppler, F., J.T.G. Hamilton, M. Braß, T. Röckmann - Methane emissions from terrestrial plants under aerobic conditions - Nature 187-191, doi:10.1038/ nature 04420, 187-191, 2006

Kleinhans, M.G., B.T. Grasmeijer - Bed load transport on the shoreface by currents and waves - Coastal Engineering 53, 983-996, doi:10.1016/ j.coastaleng/ 2006.06.009, 2006

Legg, S., K.M.H. Huijts - Preliminary simulations of internal waves and mixing generated by finite amplitude tidal flow over isolated topography - Deep Sea Research (part II), 53, 140-156, 2006

Lelieveld, J., C.A.M. Brenninkmeijer, P. Joeckel, I.S.A. Isaksen, M.C. Krol, J.E. Mak, E. Dlugokencky, S.A. Montzka, P.C. Novelli, W. Peters, P.P. Tans - New Directions: Watching over tropospheric hydroxyl (OH) - Atmospheric Environment 40, 5741-5743, 2006

Meirink, J.F., H.J. Eskes, A.P.H. Goede - Sensitivity analysis of methane emissions derived from SCIA-MACHY observations through inverse modeling - Atmospheric Chemistry and Physics 6, 1275-1292, 2006

Nauw, J.J., H.M. van Aken, J.R.E. Lutjeharms, W.P.M. de Ruijter - Intrathermocline eddies in the Southern Indian Ocean - Journal of Geophysical Research 111 (C03006), doi:10.1029/2005JC002917, 2006

Nick, F.M., J. Oerlemans - Dynamics of calving glaciers: comparison of three models - Journal of Glaciology 51 (177), 183-190, 2006

Oerlemans, J., F.M. Nick - Modelling the advance-retreat cycle of a tidewater glacier with simple sediment dynamics - Global and Planetary Change 50, 99-111, 2006

Oerlemans, J., D. Dahl-Jensen, V. Masson-Delmotte - Ice sheets and sea level - (Letter to)Science 313, 1043-1044, 2006

Omta, A.W., J. Bruggeman, S.A.L.M. Kooijman, H.A. Dijkstra - Biological carbon pump revisited: Feedback mechanisms between climate and the Redfield ratio - Geophysical Research Letters 33, L14613, doi:10.1029/2006GL026213, 2006

Palastanga, V., P.J. van Leeuwen, W.P.M. de Ruijter - A link between low-frequency mesoscale eddy variability around Madagascar and the large-scale Indian Ocean variability - Journal of Geophysical Research 111, (C098029), doi:10.1029/ 2005JC003081, 2006

Quartel, S., E.A. Addink, B.G. Ruessink - Object-oriented extraction of beach morphology from video images - International Journal of Applied Earth Observation and Geoinformation 8(4), 256-269, 2006

Rhee, T.S., C.A.M. Brenninkmeijer, T. Röckmann - The overwhelming role of soils in the global atmospheric hydrogen cycle - Atmospheric Chemistry and Physics 6, 1611-1625, 2006

Roelofs, G.-J., P. Stier, J. Feichter, E. Vignati, J. Wilson - Aerosol activation and cloud processing in the global aerosol-climate model ECHAM5-HAM - Atmospheric Chemistry and Physics Discussions 6, 519-548, 2006

Ruessink, B.G. - A Bayesian estimation of parameter-induced uncertainty in a nearshore alongshore current model - Journal of Hydroinformatics 8(1), 37-49, doi:10.2166/jh.2006.009, 2006

Ruessink, B.G., K.T. Houwman, B.T. Grasmeijer - Modeling the nonlinear effect of wind on rectilinear tidal flow - Journal of Geophysical Research 111, C10002, doi:10.1029/2006JC003570, 2006

Schaeffer, M., B. Eickhout, M. Hoogwijk, B. Strengers, D. van Vuuren, R. Leemans, J.D. Opsteegh - CO_2 and albedo climate impacts of extra-tropical carbon and biomass plantations - Global Biogeochemical Cycles 20, GB2020, doi: 10.1029/2005GB002581, 2006

Shaheen, R., C. Janssen, T. Röckmann - Investigations of the photochemical isotope equilibrium between O_2, CO_2 and O_3 - Atmospheric Chemistry and Physical Discussions 6, 7869-7904, 2006

Shindell, D.T., G. Faluvegi, D.S. Stevenson, M.C. Krol, L.K. Emmons, J.-F. Lamarque, G. Pétron, F.J. Dentener, K. Ellingsen, M.G. Schultz, O. Wild, M. Amann, C.S. Atherton, D.J. Bergmann, I. Bey, T. Butler, J. Cofala, W.J. Collins, R. G. Derwent, R.M. Doherty, J. Drevet, H.J. Eskes, A.M. Fiore, M. Gauss, D.A. Hauglustaine, L.W. Horowitz, I.S.A. Isaksen, M.G. Lawrence, V. Montanaro, J.-F Müller, G. Pitari, M.J. Prather, J.A. Pyle, S. Rast, J.M. Rodriguez, M.G. Sanderson, N.H. Savage, S.E. Strahan, K. Sudo, S. Szopa, N. Unger, T.P.C. van Noije, G. Zeng - Multi-model simulations of carbon monoxide: Comparison with observations and projected near-future changes - Journal of Geophysical Research 111 (D19306), DOI:19310.11029/12006JD007100, 2006

Sima, A., M. Schultz, A. Paul, J. Oerlemans - Modeling the oxygen-isotopic composition of the North American Ice Sheet and its effect on the isotopic composition of the ocean during the last glacial cycle - Geophysical Research Letters 33, L15706, doi:10.1029/2006GL026923, 2006

Spada, F., M.C. Krol, P. Stammes - McSCIA: application of the equivalence Theorem in a Monte Carlo radiative transfer model for spherical shell atmospheres - Atmospheric Chemistry and Physics Discussions 6, 1199-1248, 2006

Stevenson, D.S., F.J. Dentener, M.G. Schultz, K. Ellingsen, T.P.C. van Noije, O.Wild, G. Zeng, M. Amann, C.S. Atherton, N. Bell, D.J. Bergmann, I. Bey, T. Butler, J. Cofala, W.J. Collins, R.G. Derwent, R.M. Doherty, J. Drevet, H.J. Eskes, A.M. Fiore, M. Gauss, D.A. Hauglustaine, L.W. Horowitz, I.S.A. Isaksen, M.C. Krol, J.-F. Lamarque, M.G. Lawrence, V. Montanaro, J.-F. Müller, G. Pitari, M.J. Prather, J.A. Pyle, S. Rast, J.M. Rodriguez, M.G. Sanderson, N.H. Savage, D.T. Shindell, S.E. Strahan, K. Sudo, S. Szopa - Multimodel ensemble simulations of present-day and near-future tropospheric ozone,

- Journal of Geophysical Research 111 (D08301), doi:08310.01029/02005JD006338, 2006

Tarasova, O.A., C.A.M. Brenninkmeijer, S.S. Assonov, N.F. Elansky, T. Röckmann, M. Brass - Atmospheric CH_4 along the Trans-Siberian Railroad (TROICA) and River Ob: Source Identification using stable isotope analysis - Atmospherical Environment 40, 5617-5628, 2006

Tsigaridis, K., M.C. Krol, F.J. Dentener, Y. Balkanski, J. Lathière, S. Metzger, D.Hauglustaine, M. Kanakidou - Change in global aerosol composition since preindustrial times - Atmospheric Chemistry and Physics Discussions 6, 5585- 5628, 2006

Van As, D., M.R. van den Broeke, M.M. Helsen - Structure and dynamics of the summertime atmospheric boundary layer over the Antarctic plateau, I: Measurements and model validation - Journal of Geophysical Research 111 (D007102), doi:10.1029/2005JD005948, 2006

Van As, D., M.R. van den Broeke - Structure and dynamics of the summertime atmospheric boundary layer over the Antarctic plateau, II: Heat, momentum and moisture budgets - Journal of Geophysical Research 111 (D007103), doi:10.1029/ 2005JD006956, 2006

Van de Berg, W.J., M.R. van den Broeke, C.H. Reijmer, E. van Meijgaard - Characteristics of the Antarctic surface mass balance, 1958-2002, using a regional atmospheric climate model - Annals of Glaciology 41, 97-104, 2006

Van den Berg, J., R.S.W. van de Wal, J. Oerlemans - Recovering lateral variation in lithospheric strength from bedrock motion data using a coupled ice sheet-lithosphere model - Journal of Geophysical Research 111, doi:10.1029/2005JB003790, 2006

Van den Berg, J., R.S.W. van de Wal, J. Oerlemans - Effects of spatial discretizatio in ice-sheet modelling using the shallow-ice approximation - Journal of Glaciology 52, 89-98, 2006

Van de Berg, W. J., M.R. van den Broeke, E. van Meijgaard, C.H. Reijmer - Reassessment of the Antarctic surface mass balance using calibrated output of a regional atmospheric climate model - Journal of Geophysical Research 111 (D11104), doi:10.1029/2005JD006495, 2006

Van den Broeke, M.R., W.J. van de Berg, E. van Meijgaard - Snowfall in coastal West Antarctica much greater than previously assumed - Geophysical Research Letters 33, L02505, doi:10.1029/ 2005GL025239, 2006

Van den Broeke, M.R., C.H. Reijmer, D. van As, W. Boot - Daily cycle of the surface energy balance in Antarctica and the influence of clouds - International Journal of Climatology 26, 1587-1605, 2006

Van den Broeke, M.R., W.J. van de Berg, E. van Meijgaard, C.H. Reijmer - Identification of Antarctic ablation areas using a regional atmospheric climate model - Journal of Geophysical Research 111 (D18110), doi:10.1029/2006JD007127, 2006

Van den Broeke, M. R. - Towards quantifying the contribution of the Antarctic ice sheet to global sea level change - Journal de Physique IV France 139, 179–187, 2006

Van der Vegt, M., H.M. Schuttelaars, H.E. de Swart - Modeling the equilibrium of tide-dominated ebb-tidal deltas - Journal of Geophysical Research 111 (F02013), doi:10.1029/2005JF000312, 2006

Van Noije, T.P.C., H.J. Eskes, F.J. Dentener, D.S. Stevenson, K. Ellingsen, M.G. Schultz, O. Wild, M. Amann, C.S. Atherton, D.J. Bergmann, I. Bey, K.F. Boersma, T. Butler, J. Cofala, J. Drevet, A.M. Fiore, M. Gauss, D.A. Hauglustaine, L.W. Horowitz, I.S.A. Isaksen, M.C. Krol, J.-F. Lamarque, M.G. Lawrence, R.V. Martin, V. Montanaro, J.-F. Müller, G. Pitari, M.J. Prather, J.A. Pyle, A. Richter, J.M. Rodriguez, N.H. Savage, S.E. Strahan, K. Sudo, S. Szopa, M. van Roozendael - Multi-model ensemble simulations of tropospheric NO_2 compared with GOME retrievals for the year 2000 - Atmospheric Chemistry and Physics 6, 2943-2979, 2006

Von der Heydt, A.S., H.A. Dijkstra - The effect of ocean gateways on the global ocean circulation in the late oligocene and early miocene - Paleoceanography 21 (PA1011), doi:10.1029/2005PA001149, 2006

Warneke, T., J.F. Meirink, P. Bergamaschi, J.-U. Grooß, J. Notholt, G.C. Toon, V. Velazco, A.P.H. Goede, O. Schrems - Seasonal and latitudinal variation of atmospheric methane: A ground-based and ship-borne solar IR spectroscopic study - Geophysical Research Letters 33, L14812, doi:10.1029/2006GL025874, 2006

Wilschut, F., R. Bintanja, R.S.W. van de Wal - Ice-sheet modelling characteristics in sea-level-based temperature reconstructions over the last glacial cycle - Journal of Glaciology 52, 176, 2006

Wubs, F.W., A.C. de Niet, H.A. Dijkstra - The performance of implicit ocean models on B- and C-grids - Journal of Computational Physics 211, 210-228, 2006

Zahn, A., P. Franz, C. Bechtel, T. Röckmann
Modelling the budget of middle atmospheric water vapour isotopes
Atmospheric Chemistry and Physics 6, 2073- 2090, 2006

6. Dissertations

Donners, J., 12 January 2005

The role of the South Atlantic in the upper branch of the global thermohaline circulation

Promotor prof.dr. W.P.M. de Ruijter

Co-promotor dr. S.S. Drijfhout (KNMI)

Van Aalst, M.K., 20 January 2005

Dynamics and transport in the stratosphere: simulations with a general circulation model

Promotores prof.dr. J. Lelieveld and prof.dr. P. Crutzen (MPI Mainz)

De Steur, L., 10 February 2005

Stirred, not mixed: a study on the decay of Agulhas rings

Promotor prof.dr. W.P.M. de Ruijter

Co-promotor dr. P.J. van Leeuwen

Van den Brink, H.W., 14 March 2005

Extreme winds and sea-surges in climate models

Promotor prof.dr.ir. J.D. Opsteegh

Co-promotor dr. G.P. Können (KNMI)

Zelle, H.D., 9 May 2005

On the evolution of sea surface temperature in the tropical Pacific

Promotores prof.dr. G.J. Komen and prof.dr. B.A.C. Ambrosius (TU Delft)

Co-promotor dr. G.J.H. Burgers

Hosegood, P., 10 May 2005

Observations of the impact of flow-topography interactions on mixing processes within a confined basin: the Faeroe Shetland Channel

Promotor prof.dr. J.T.F. Zimmerman

Co-promotor dr. J.J.M. van Haren (NIOZ)

Van Veldhoven, A.K., 3 October 2005

Observations of the evolution of Agulhas Rings

Promotor prof.dr. W.P.M. de Ruijter

Co-promotor dr. H.M. van Aken (NIOZ)

Van As, D., 5 October 2005

The summertime atmospheric boundary layer over the Antarctic Plateau

Promotor prof.dr. J. Oerlemans

Co-promotor dr. M.R. van den Broeke

Schaeffer, M., 16 December 2005

Jazzing up the climate debate : exploring non-linear behavior in the climate system to feed into policy discussions

Promotores prof.dr.ir. J.D. Opsteegh and prof.dr. H.B.J. Leemans (WUR)

Co-promotor dr.ir. F.M. Selten (KNMI)

Helsen, M.M., 8 February 2006

On the interpretation of stable isotopes in Antarctic precipitation

Promotor prof.dr. J. Oerlemans

Co-promotores dr. R.S.W. van de Wal and M.R. van den Broeke

Van der Vegt, M., 20 March 2006

Modeling the dynamics of barrier coasts and ebb-tidal deltas

Promotor prof.dr. H.E. de Swart and prof.dr. W.P.M. de Ruijter

Co-promotor dr. H.M. Schuttelaars

De Vries, H., 13 June 2006

Dynamics of synoptic-scale cyclones: a conceptual view based on potential vorticity building blocks and the theory of optimal perturbations

Promotor prof.dr.ir. J.D. Opsteegh

Nick, F.M., 8 September 2006

Modelling the behaviour of tidewater glaciers

Promotor prof.dr. J. Oerlemans

7. Summer schools

Glaciers and ice sheets in the climate system

13 - 24 September 2005

organized and sponsored by IMAU; co-sponsored by the Autonomic Province of Alto Adige

convenor: J. Oerlemans

venue: Karthaus, Italy

37 Ph.D. students and junior scientists

teaching staff: D. Dahl-Jenssen, A. Fowler, J.W. Greuell, H. Gudmunddson, A. Jenkins, G. Kaser, K. Lambeck, R. Mulvaney, J. Oerlemans, T. Payne, C.H. Tijm-Reijmer, A. Stroeven

Dynamics and Evolution of Cenozoic Climate

organized and sponsored by IMAU, Università di Urbino, Darwin Center for Biogeology, USSP Consortium, NSG

convenors: R. v.d. Wal, S. Galeotti, H. Brinkhuis

venue: Urbino, Italy

45 PhD students and junior scientists

teaching staff: H. Brinkhuis, K. Caldeira, M. Collinson, G. Cortese, R. DeConto, G. Dickens, A. von der Heydt, S. Galeotti, M. Huber, P. Koch, L. Lanci, L. Lourens, M. Pagani, H. Pälike, P. Pearson, I. Premoli-Silva, I. Raffi, M. Rampino, G.-J. Reichart, S. Schellenberg, A. Sluijs, H. Spero, C. Stickley, E. Thomas, R. v.d. Wal, J. Zachos

Utrecht Summerschool Physics of the Climate System

organized and sponsored by IMAU, Department of Physics and Astronomy (Utrecht University)

convenors: J. Oerlemans, G.M. Terra

venue: Utrecht, The Netherlands

20 students

teaching staff: M.R. van den Broeke, A.J. van Delden, P.J. van Leeuwen, J. Oerlemans, J.D. Opsteegh, T. Röckmann, G.J. Roelofs, W.P.M. de Ruijter, G. Terra.

Measurement Techniques in Atmospheric Chemistry

7 – 13 October 2006

organized and sponsored by IMAU and MPI for Chemistry Mainz

convenors: T. Röckmann and J. Lelieveld

venue: Oberwesel, Germany

44 Ph.D. students and junior scientists

teaching staff: A. Ansmann, T.v. Clarmann, J. Crowley, H. Dolman, F. Drewnick, H. Fischer, T. Hoffmann, R. Holzinger, P. Hoppe, R. Koppmann, T. Kuhlbusch, H. Meijer, O. Moehler, J. Notholt, U. Platt, U. Pöschl, T. Röckmann, T. Wagner

8. Projects 2005/2006

Project title	Funding	Project leader
Propagation of equatorial climate variability of the Southwest Indian Ocean	NWO/ALW	De Ruijter
Retroflection and ring formation of ocean currents	NWO/ALW	De Ruijter
Outer delta dynamics: process analysis of water motion, sediment transport and morphological variability	NWO/ALW	De Swart, Kroon
Effect of climate change and human interventions on the dynamics of turbidity maxima in estuaries: coupling of morphology and biology	NWO/ALW	De Swart
Transport and circulation around Madagascar	NWO/ALW	Van Leeuwen
Mass Balance observations on the Greenland ice sheet	NWO (NAP)	Van de Wal
Interpretation and measurements of isotopes and gas in Antarctica (part A)	NWO/ALW (NAAP)	Van de Wal
Long-term monitoring of Antarctic climate using Automatic Weather Stations (2005-2012)	NWO/ALW (NAAP)	Van den Broeke
Mass balance and fresh water contribution of the Greenland ice sheet: a combined modelling and observational approach	NWO/ALW RAPID	Van den Broeke
European Project on Ice coring in Antarctica (EPICA-NL-2)	NWO/ALW	Van den Broeke
Long-term high resolution of the climate and mass balance of the Antarctic ice sheet	NWO/ALW	Van den Broeke
Netherlands Participation in the Greenland Climate Network (GC-NET)	NWO/ALW (NAP)	Van den Broeke
Climate of the west Greenland ablation zone: towards an IPY activity in 2008	NWO/ALW (NAP)	Van den Broeke
Ice and Climate-programme (SPINOZA)	NWO	Oerlemans
The dynamic response of Arctic glaciers to global warming (GLACIODYN)	NWO/ALW (IPY-NL)	Oerlemans

NWO IPY coordination	NWO/ALW (IPY-NL)	Oerlemans
Atmospheric variability and the Atlantic Multidecadal Oscillation. Part A: Dynamical analysis of a coupled ocean-atmosphere model	NWO/ALW	Dijkstra
A new approach to the spin-up problem in ocean-climate models. Part B – Towards iCCSM 3.0	NWO/ALW	Dijkstra
Experimental and model analysis of aerosol activation in the Netherlands	NWO/ALW	Roelofs
H2 budget	NWO/ALW	Röckmann
Meltwater input, flow and calving of Arctic glaciers	NWO/ALW (IPY-NL)	Tijm-Reijmer
Reconstruction of the time-mean absolute velocity field of the ocean circulation	NWO/STW	Dijkstra
Airborne measurements of radiances in cloudy conditions	NWO/STW	Van Dop
Delta morphodynamics – Red River Delta Vietnam	NWO/WOTRO	Hoekstra
East Kalimantan Coastal Zone Research Programme	NWO/ALW/WOTRO-KNAW	Hoekstra/Hoitink
Machine-independent version of CCSM3	NWO/NCF	Dijkstra
Parallelisation of Antarctic Ice Sheet model	NWO/NCF	Van den Wal
Data-model integration: a new approach to understanding and forecasting temporal sandbar behaviour	NWO-VIDI	Ruessink
River Bifurcations in meandering rivers on lowland deltaic planes	NWO-VENI	Kleinhans/Hoekstra
Ocean circulation and continental drift: A new systematic approach	NWO-VENI	v.d. Heydt/Dijkstra
Framework programme Space Research System Earth: Absolute ocean velocity using the GOCE satellite and inverse modelling	SRON	Van Leeuwen/De Ruijter
Framework programme Space Research System Earth: Global modelling of greenhouse gases using the TM5 model	SRON	Röckmann
Dynamics and sensitivities of the Indian-Atlantic Ocean exchange using altimetry and GOCE gravity observations	SRON	Van Leeuwen

Monte Carlo radiative transfer in spherical geometry applied to the satellite measurements from SCIAMACHY	SRON	Van Dop/Krol
Improving Methane Emission estimates Aided by Satellite data (IMEAS)	SRON	Röckmann
North-Atlantic Ocean Monitoring and Modelling	BSIK	Van Leeuwen
Impact of upstream anomalies in the Agulhas Current system on the inter-ocean exchange and primary production around Southern Africa.	EU/Marie Curie	De Ruijter
Sandpit	EU	Hoekstra
SANDS	EU	Ruessink/Kleinhans
Human interaction with large scale morphological evolution (HUMOR)	EU	Kroon/De Swart
CoastView	EU	Kroon
Space born measurements of Arctic glaciers and implications for sea-level (SPICE)	EU	Oerlemans
Enhanced Paleoreconstruction and Integrated Climate Analysis through Marine and Ice core Studies (EPICA-MIS)	EU	Van den Broeke
A European Network for Atmospheric Hydrogen observation and studies (EUROHYDROS)	EU	Röckmann
Stratospheric-Climate Links with Emphasis on the upper troposphere and lower stratosphere (SCOUT-03)	EU	Röckmann
Marine Environment and Security for the European Area (MERSEA)	EU	Van Leeuwen
Shell source rock	Shell/SenterNovem	Van de Wal/Dijkstra
Investigation of formation and processing of aerosol using isotope measurements on aerosols (in particular the oxygen isotope anomaly)	Japan Society for the promotion of Science	Röckmann
Intercomparison of wave data based on ADCP's and conventional Wave buoys	RWS-RIKZ	Hoitink/Ruessink/Hoekstra
Morphology and Ecology of the Wadden islands in the framework of nature restoration	RWS/RIKZ	Hoekstra
Dynamics of nearshore oblique sand bars: data analysis and modelling	UU/EU/IMAU	De Swart/Kroon
Beach- and surfzone processes: the intertidal beach (ARGUS project)	UU/ARGUS	Ruessink
Tidal inlets and ebb tidal deltas	UU	Hoekstra

Modelling the surface albedo of snow and ice surfaces	UU	Tijm-Reijmer
Cyclogenesis and non-model wave growth	UU	Opsteegh/Van Delden
Modelling of estuarine turbidity maxima	UU	De Swart
Large eddy simulation of katabatic flows	UU	Van Dop
A model study of warm cloud dynamics-micro-physics and precipitation formation	UU	Roelofs
Antarctic climate studies	IMAU/UU	Van den Broeke
Changes in the global ocean circulation over the last 65 Ma	IMAU/UU	Dijkstra/Van de Wal
Investigation of organic trace gas budgets in the atmosphere with isotope techniques	IMAU/UU	Röckmann
Investigation of organic trace gas budgets, at-mosphere transport and oxidation capacity with isotope techniques.	IMAU/UU	Röckmann/Holzinger
The Agulhas current system: a key control of At-lantic climate	IMAU/UU	Dijkstra
Cyclogenesis and wave breaking at the tropo-pause and associated stratosphere-troposphere exchange	IMAU/UU	Opsteegh/Van Delden
Synoptic setting and forecasting of thunder-storms	IMAU/UU	Van Delden
The effect of surfacing dust layers on the evolu-tion of the Greenland ice sheet.	IMAU/UU	Oerlemans
On the Indian Ocean's role in the global thermo-haline circulation (THC)	IMAU/UU	De Ruijter/Dijkstra
Inception of the Antarctic ice sheet	UCG/UU	Van de Wal
Mechanisms underlying the Greenhouse-Ice-house transition; modelling the Eocene-Oligocene boundary	UCG/UU	Van de Wal
The temporal and spatial dynamics of shoreline sandwaves	UCG/UU	Ruessink
Coastal systems and lowland river systems	UCG/UU	Hoekstra/ Ruessink

Ph.D. students:	status on January 1, 2003:	24
	status on January 1, 2004:	21
	status on January 1, 2005:	20
	status on January 1, 2006:	29
	status on January 1, 2007	32

Postdocs:	status on January 1, 2003:	18
	status on January 1, 2004:	18
	status on January 1, 2005:	13
	status on January 1, 2006:	15
	status on January 1, 2007	15

9. Management team

Director

Prof.dr. W.P.M. de Ruijter (from 1-11-2006)

Prof.dr. J. Oerlemans (until 1-11-2006)

Members of the Governing Board

Prof.dr. J. Oerlemans

Prof.dr. W.P.M. de Ruijter (from 1-2-06)

Dr. H.E. de Swart (until 1-9-05)

Prof.dr. P. Hoekstra

Prof.dr.ir. J.D. Opsteegh

Dr. G.J. Roelofs (until 1-5-05)

Dr. P.J. van Leeuwen (until 1-2-06)

Prof.dr. T. Röckmann (from 1-5-05)

Prof.dr.ir. H.A. Dijkstra (from 1-2-06)

Drs. E.I. de Koning

Colophon

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