BIENNIAL REPORT 2003 – 2004

INTERNATIONAL METEOROLOGICAL INSTITUTE IN STOCKHOLM

DEPARTMENT OF METEOROLOGY, STOCKHOLM UNIVERSITY

FRONT COVER | Picture of Odin, courtesy of Swedish Space Corporation.

INTERNATIONAL METEOROLOGICAL INSTITUTE IN STOCKHOLM (IMI) AND DEPARTMENT OF METEOROLOGY, STOCKHOLM UNIVERSITY (MISU)

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Postal address
Department of Meteorology
Stockholm University
S-106 91 Stockholm, Sweden

Telephone

Int.	+46-8-16 23 95	Nat.	08-16 23 95

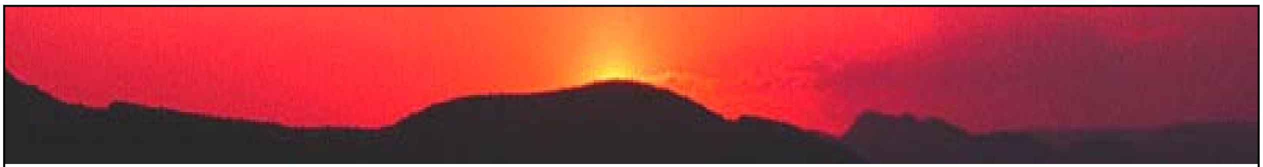
Telefax

Int.	+46-8-15 71 85	Nat.	08-15 71 85

E-mail
imi@misu.su.se

Internet
www.misu.su.se

INNEHÅLLSFÖRTECKNING



THE INSTITUTE

THE INTERNATIONAL METEOROLOGICAL INSTITUTE IN STOCKHOLM

The International Meteorological Institute in Stockholm (IMI) was created in 1955 by a decision of the Swedish Parliament with the objective "to conduct research in meteorology and associated fields and to promote international scientific co-operation within meteorology". This decision was a result of initiatives taken by Professor Carl-Gustaf Rossby, strongly supported by the former Minister for Foreign Affairs of Sweden, Richard Sandler.

The most important function of the institute is to provide opportunities for foreign scientists to work in Sweden for varying periods of time in close collaboration with their Swedish colleagues.

The institute is financed by a direct contribution from the Swedish Government and indirectly through Stockholm University by the fact that its Department of Meteorology is an integral part of the institute.

GOVERNING BOARD

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THE DEPARTMENT OF METEOROLOGY AT STOCKHOLM UNIVERSITY

The Department of Meteorology at Stockholm University (MISU) was established in 1947 when Carl-Gustaf Rossby assumed the duties of the chair which was created for him by Stockholm’s Högskola (later Stockholm University). The small research group that Rossby created soon developed into a successful department now consisting of more than 60 people, including some 20 graduate students. At Rossby’s death in 1957 Bert Bolin took over the leadership of the department, a role that he maintained for almost three decades.

The Department of Meteorology is organizationally tied to the Physics and Mathematics Section of the Faculty of Science at Stockholm University. The International Meteorological Institute is an integral part of the department, but with a separate economy.

HEAD OF THE DEPARTMENT

Erland Källén, Professor of Dynamic Meteorology.

INTRODUCTION

INTRODUCTION

The extensive international network in the field of atmospheric science and oceanography established at the institute has provided an excellent platform for co-operative research. This co-operation is directed to fundamental research as well as to providing scientific knowledge in the development of society on the national and international levels. The specific scientific research projects are dealt with in some detail in the following chapters. The present introduction outlines a few ongoing major international collaborative activities.

A broad spectrum of international activities has characterized the work at the institute during the past years, including participation in the World Climate Research Programme (WCRP) the International Geosphere-Biosphere Programme (IGBP) and several international research projects funded by the European Commission and the European Space Agency (ESA).

International co-operation in the area of dynamic meteorology takes place both within several international programs and with individual universities or laboratories. Within European programs there is collaboration within ESA programmes for satellite observations; ESA plans to launch a research satellite in 2008, dedicated to wind measurements using a Doppler lidar technique, the Atmospheric Dynamics – Aeolus mission.

Several projects concern model development. The Arctic Model Intercomparison Project (ARCMIP) aims at improving modeling of Arctic processes in climate models and the GEWEX Atmospheric Boundary Layer Study (GABLS) at improving boundary-layer descriptions in general. In these projects, there is an active collaboration with several research groups in Europe and USA. Morover, there is a long-standing collaboration with the Naval Research Laboratory on improving the COAMPS™ atmospheric model.

Work is ongoing to finalize the evaluation of the results from the expedition to the high Arctic, the Arctic Ocean Experiment 2001 (AOE-2001), which took place in June - September 2001. This work is performed in close collaboration with a large number of participants in Europe and the USA. Preparations are now underway for a new Arctic expedition – the Arctic Summer Cloud-Surface Study (ASCOS) within the International Polar Year (IPY) in 2007/08. This expedition is aimed at understanding the formation and lifetime of Arctic summer low clouds, their microphysics and relations to boundary-layer processes and to natural formation of aerosol particles, as well as their effects on climate.

The Atmospheric physics group is involved in a number of satellite missions, rocket projects and ground-based measurement networks of which studies related to the Odin satellite make up a major part. Since the early 1990s, intensive work on the preparation of the project was based on collaboration with scientific groups mainly in France, Finland and Canada. After Odin's successful launch on February 20, 2001, these international activities have been greatly intensified.

A rocket carrying instruments developed as part of the MAGIC project was launched within an international campaign from Esrange, Sweden, in January 2005. Preparations are also underway at the institute to build instruments for the extended ALOMAR Research Initiative (eARI), an opportunity funded by the European Commission to launch scientific instruments on rocket payloads from Andøya, Norway, in 2006/2007.

Kevin Noone is currently on leave to hold the position as Executive Director of IGBP. Erland Källén and Gunilla Svensson have taken an active part in the Arctic Climate Impact Assessment (ACIA); Caroline Leck is a member of the International Commission on Atmospheric Chemistry and Global Pollution (CACGP) of ICSU and Surface Ocean Lower Atmosphere Study (SOLAS) implementation committee; Gunilla Svensson is a member of the GEWEX Atmospheric Boundary Layer (GABLS) Science Panel; Henning Rodhe is a member of the ABC Science Team; Erland Källén is the chairman of the ECMWF Scientific Advisory Committee; Michael Tjernström is a member of the Science Steering Group of the International study of Arctic Change (ISAC) and the Chairman of the Swedish IGBP/WCRP committee.

RESEARCH ACTIVITIES

RESEARCH ACTIVITIES

The different research activities in this section have been divided as follows:

- DYNAMIC METEOROLOGY
- PHYSICAL OCEANOGRAPHY
- CHEMICAL METEOROLOGY
- ATMOSPHERIC PHYSICS
- ARCTIC STUDIES

DYNAMIC METEOROLOGY

BOUNDARY LAYER AND MESOSCALE DYNAMICS

This field of research concerns the smallest scales of atmospheric motions, not resolved in climate models or in operational NWP models. Much of the work at the institute thus revolves around the use and development of high-resolution mesoscale models. In contrast to mesoscale circulations, boundary layer turbulence is not resolvable in models, nor is it deterministic in its details. The statistics of turbulent flows is, however, to some degree deterministic. Much of the work in this field is directed at determining the effects of turbulence on the mean flow, to improve larger-scale numerical models. Conversely, this means that one must also understand the effect on the turbulence of the mean conditions. Much of the work done at the institute involves participating in, and using data from, field campaigns.

The main modelling tool used at the institute is the US Navy COAMPS™ atmospheric model. It is applied to coastal meteorology, Arctic meteorology, katabatic flows over melting glaciers and air pollution transport studies. Most of the work has taken place within international research projects, such as ARCMIP. There is also a long-standing collaboration with the Marine Meteorology Division of the US Naval Research Laboratory, where COAMPS™ is developed and maintained.

Work on turbulence dynamics has been directed at three areas: the Arctic boundary layer, interaction between turbulence and clouds and boundary layers in high static-stability conditions. The work is carried out within programs such as GABLS, and also involves field experiments in the Arctic, for example AOE-2001 and SHEBA.

Local scaling of turbulence in coastal wind jets

Michael Tjernström, Stefan Söderberg and Ian Brooks (Leeds University)

Along-coast wind-jets often form along mountainous coastlines, in response to the coastal baroclinicity. A consequence of the resulting strong northerly flow along the US West Coast is upwelling of cold water. Due to the jet, this flow is often supercritical (Fr>1) and becomes sensitive to changes in the coastline geometry. Expansion fans form at capes when the coastline turns away from the flow, which further enhances upwelling by a positive stress-vector curl. The coastal jet is not a streamline and air in the jet accelerates from offshore in over a much colder water surface. Very stable internal boundary layers thus form downstream of major headlands. Turbulence measurements from the Coastal Waves 1996 (CW96) experiment were analyzed using so-called local scaling. Theory indicates that locally scaled velocity variances have universal and constant values.

However, in data from many experiments, fluxes drop off more rapidly with increasing stability than variances, and scaled variances thus in-crease with stability. Our data is no exception.

Turbulence modeling with the MIUU-model is in very good agreement with the observations. However, the very same model results also conform to another data sets, with observations at near-neutral conditions. For that data set it can be shown that scaled variances deviates from the constant value due to a non-local imbalance in the turbulent kinetic energy equation. We thus hypothesize that the same is true for the CW96 case and that indeed, all cases when the locally scaled velocity variances deviate from a constant value are caused by such imbalances. This would seem to explain the lack of a universal shape of scaled velocity variances with stability. The shape is different in different experiments simply because the physics, causing the imbalance as a function of stability, is different for different types of stably stratified flows.

References

Söderberg, S., and M. Tjernström. 2002. Transitions in Supercritical Flows Along Mountain-ous Coastlines: On the Diurnal Cycle, Journal of Atmospheric Sciences, 59, 2615-2624

Brooks, I., S. Söderberg and M. Tjernström. 2003. The turbulence structure of the stable atmospheric boundary layer around a coastal headland: Aircraft observations and modeling results. Boundary-Layer Meteorology, 107, 531-559

Ström, L., and M. Tjernström. 2004. Variability in the summertime coastal marine atmospheric boundary layer off California, Quarterly Journal of the Royal Meteorological Society, 130, 423 – 448

Energy similarity – a new turbulence closure model for stably stratified atmospheric boundary layers.

Thorsten Mauritsen, Gunilla Svensson, Sergej Zilitinkevich (University of Helsinki, Finland), Leif Enger (Uppsala University, Sweden) and Branko Grisogono (Zagreb University, Croatia)

A new way of scaling turbulent fluxes in shear driven stably stratified boundary layers is proposed. Here, the fluxes of momentum and potential temperature are nondimensionalized by the variance of velocity and temperature. The normalized fluxes are then scaled using the gradient Richardson number, Ri. For near neutral stratification, these normalized fluxes are found to be nearly constant. At Ri>0.1, they behave quite differently. The normalized temperature flux goes to zero, while the normalized momentum flux stays finite, even for very large Ri. The normalized humidity flux acts opposite to the normalized heat flux.

The results from the scaling are used to obtain turbulence closure in an atmospheric model. Here the fluxes of momentum and potential temperature are calculated from prognostic turbulent kinetic energy, temperature variance and stability. The model is tested on a weakly stable case. The results resemble those of large eddy simulations.

Numerical modelling of katabatic flow

Stefan Söderberg, Oskar Parmhed, Michael Tjernström and Branko Grisogono (Zagreb University, Croatia)

Katabatic flows occur over sloping surfaces that are cooled relative to the ambient air. It is, however, notoriously difficult to model such flows due to several circumstances; the jet-shaped flow is very shallow and the static stability is usually strong. In this study we apply the COAMPS™ mesoscale model to Breidamerkulljökull, an outflow glacier in the Vattnajökull complex. In this particular application the model has three nests with a horizontal resolution of 3 km in the innermost nest and the vertical resolution is also high

The simulation results agree reasonably well with measurements from a field experiment on this glacier. Two factors are found to contribute to the frequent occurrence of katabatic flow here. First, the melting snow surface maintains a surface temperature close to 0ºC, while the air temperature warms adiabatically as the air descends the slope. This provides a "self enhanced" negative buoyancy, that drives the flow to a balance with local friction. Second, the jet-like shape of the resulting flow provides a large so-called "curvature-term" in the Scorer parameter, which becomes negative in the upper jet. This prevents vertical wave propagation and isolates the very shallow boundary layer from influence from the free troposphere aloft.

The modeled turbulence structure conforms in principle to the same local scaling as found in coastal jets off the US West Coast, and resembles that observed in katabatic flows over Alpine glaciers, with one notable difference. The strong persistence of this flow maintains a low-level down-glacier flow for practically all large-scale wind directions. In this case, the wind direction thus changes enough to maintain a wind shear even where the scalar wind speed approaches its maximum. Thus the momentum flux remains larger than zero through the katabatic jet.

GABLS (GEWEX Atmospheric Boundary Layer Experiment)

Gunilla Svensson, Thorsten Mauritsen, Bert Holtslag (Wageningen University, The Netherlands) and many others

A first model intercomparison study has been performed within the GABLS project. GABLS is intended for intercomparison of parameterizations used in numerical weather prediction models and climate models. As a first experiment, a weakly stably stratified case was simulated with 19 participating models. These models range from operational forecast models to higher order closure research models – we participated with two research models. The results from the intecomparison clearly show that the operational models generate deeper boundary layers as a consequence of using boundary-layer schemes that enhance turbulent mixing while the research models show close agreement with results from Large Eddy Simulations of the same case.

This enhanced mixing issue is explored in deeper detail when we examine the relations between the turbulence in the boundary layer and its effects on the synoptic scale circulation systems. The deeper boundary layer gives rise to a stronger cross-isobaric mass flux that has a clear connection to the lifetime of synoptic scale cyclones.

Arctic Regional Modeling – ARCMIP

Michael Tjernström, Mark Žagar, Gunilla Svensson and Johannes Kalsson, Anette Rinke and Klaus Dethloff (Alfred-Wegner Institute, Germany), John Cassano (CIRES, University of Colorado, Boulder, USA), Susanne Pfeifer and Tido Semmler (MPI for Meteorology, Germany), Klaus Wyser and Colin Jones (SMHI)

See Arctic Studies

Vertical structure of the arctic boundary layer during AOE2001

Michael Tjernström, Ola Persson (NOAA-ETL/CIRES), and Mike Jensen (University of Colorado/CIRES)

See Arctic Studies

Wave flow simulations over Arctic leads

Thorsten Mauritsen, Gunilla Svensson and Branko Grisogono (Zagreb University, Croatia)

See Arctic Studies

Temporal variability in the AOE2001 Arctic boundary layer

Michael Tjernström, Thorsten Mauritzen, Ola Persson (NOAA/ETL) and Carmen Nappo (NOAA/ATDD)

See Arctic Studies

LARGE SCALE DYNAMICS AND CLIMATE

European and north Atlantic daily to multidecadal climate variability (EMULATE)

Anders Moberg, Philip Jones (University of East Anglia, UK), Christopher Folland and David Parker (Hadley Centre, UK), Jucundus Jacobeit (University of Augsburg, Pascal Yiou, Laboratoire des Sciences du Climat et de l'Environnement, DSM-CEA Saclay, France), Manola Brunet India (Universitat Rovira i Virgili, Tarragona, Spain), Jürg Luterbacher and Heinz Wanner (University of Bern, Switzerland) and Deliang Chen (Göteborg Univ., Sweden)

EMULATE has created daily gridded fields of mean-sea-level pressure (MSLP) over the extratropical North Atlantic and Europe (25ºN to 70ºN; 70ºW to 50ºE on a 5º by 5º grid spacing), 1850 to date. The data are used to develop time series of characteristic atmospheric circulation patterns for each season, sampled on sub-monthly time scales. The database will be assessed for quality and standard errors quantified for each time step and grid-point location. Variations and trends in these patterns, and associated temperature and precipitation patterns, will be related to those evident in large-scale sea surface temperatures (SSTs) and other possible oceanic fluctuations including those of the thermohaline circulation, with the aid of atmosphere only and coupled atmosphere and ocean models. Variations in the incidence of extremes of temperature and precipitation (including drought) across Europe will be related to fluctuations and trends in the atmospheric circulation patterns on daily to multi-decadal timescales and, for temperature, to SST and possible anthropogenic factors. With the new datasets and patterns, relationships can be investigated for much longer periods than currently available. Relationships found (and their variability) will be compared with results from the Hadley Centre atmosphere-only and coupled climate models. The project will define an array of extreme events in temperature and precipitation over the last 150 years across Europe and determine the importance of atmospheric circulation changes, SST and external forcing factors. This will enable the probable impacts of anthropogenic factors on extreme events to be determined over Europe.

References

Moberg, A. and Jones, P.D. 2004. Regional Climate Model simulations of daily maximum and minimum near-surface temperatures across Europe compared with observed station data 1961-1990. Climate Dynamics. 23: 695-715, doi 10.1007/s00382-004-0464-3

Tropical data assimilation (ADM-Aeolus satellite mission)

Nedjeljka Žagar, Erland Källén, Nils Gustafsson, Ad Stoffelen and Gert-Jan Marseille (KNMI, The Netherlands), Erik Andersson, Mike Fisher and David Tan (ECMWF, Reading, England)

The Atmospheric Dynamics Mission (Aeolus) is a space-based Doppler Lidar that will measure wind profiles in the troposphere and lower stratosphere. The measurements are only performed in one direction (line of sight) and the resulting wind profiles must be handled in a comprehensive global data assimilation system in order to obtain a complete two dimensional wind field. As a preparation for this mission, which will be launched in 2007, new methods for wind data assimilation in the tropics have been developed. The method is variationally based; background error co-variances are derived from tropical wave theory. It is shown that this new method gives superior results when line of sight winds are combined with height field data. Present day tropical data assimilation systems are not well designed to handle the new type of wind information that will emerge from the Aeolus mission.

References

Stoffelen, A., J. Pailleux, E. Källén, J. M. Vaughan, L. Isaksen, P. Flamant, W. Wergen, E. Andersson, H. Schyberg, A. Culoma, R. Meynart, M. Endemann and P. Ingmann. 2005. The Atmospheric Dynamics Mission for Global Wind Field Measurement. Bulletin of the American Meteorological Society: Vol. 86, No. 1, pp. 73–87

Žagar, N., N. Gustafsson and E. Källén. 2004. Dynamical response of equatorial waves in four-dimensional variational data assimilation. Tellus, 56A, 29-46

Žagar, N., N. Gustafsson and E. Källén. 2004. Variational data assimilation in the tropics: the impact of a background error constraint. Q. J. R. Meteorol. Soc., 130, 103-125

Žagar, N. 2004. Assimilation of equatorial waves by line of sight wind observations. J. Atmos. Sci., 61, 1877-1893

Žagar, N., E. Andersson and M. Fisher. 2005. A diagnosis of the forecast errors of the ECMWF model in the tropics based on equatorial waves. Q. J. R. Meteorol. Soc. (In Press)

A 2000-year climate reconstruction for Sweden

Anders Moberg, Barbara Wohlfarth and Isabelle Gouirand (Dept. of Physical Geography and Quaternary Geology, Stockholm University) and Markku Rummukainen (SMHI)

Studies of past climate – based on natural climate archives providing climate proxy data – offer the possibility to reconstruct a wider range of past climatic conditions compared to the recent periods covered by instrumental observations. This is useful as one of the means for evaluating climate models that are used to project future climate changes. The main objectives of this project, which has a regional focus on Sweden and its neighbouring countries, are to: (i) Describe the climatic conditions in this region during the past 2000 years for improved understanding of how the climate system evolves and the underlying mechanisms of climate variability and change. (ii) Evaluate how a combination of proxy data and climate modelling can be used to reconstruct past climate.

We are currently working on a summer temperature reconstruction for the last 1600 years based on tree ring chronologies from northern Fennoscandia. Low-resolution proxies, mainly from lake sediments, will also be employed to study century-scale climate variability in the last two millennia. A 600-year long integration for a European area with the atmospheric regional model RCA3 from the Rossby Centre, driven at its boundaries by output from an integration with a global coupled atmosphere-ocean model driven by reconstructed radiative forcings (solar, volcanic aerosols, greenhouse gases), is under development. The proxy data are 'substitutes' for the missing observations and can only provide rough estimates of some aspects of the full spectrum of climate variability (mainly summer conditions, mainly temperature, with various random distortions), whereas the model output provides information about all climate variables, although only for one tentative climate evolution (only one single model realization showing one possible response to the imposed reconstructed forcing history). Even if the model certainly does not show an entirely 'correct' climate evolution, it can be used to analyse the relative importance of different factors that govern the climate evolution in Sweden. Integrated assessments of both the proxy data and the model output are expected to provide an enhanced insight in how climate has varied in Sweden, the range of variability, and the underlying causes.

Greenhouse gas warming and circulation changes

Jenny Brandefelt, Erland Källén

One important aspect of regional climate change and natural variability is the change of long wave dynamics that may result due to global warming. Results from GCM simulations of warming have been analysed in order to understand why long wave patterns change. In the Southern Hemisphere a clear link between changes in the zonal mean wind field and the amplitude and phase of stationary wave patterns has been determined. This change in long wave variability is very much a consequence of changes in the radiatively forced, average flow of the Southern Hemisphere. On a regional scale changes in long waves may very well give rise to local climate change that can be significantly different from the global mean change. The mechanisms investigated also have consequences for changes in extreme weather patterns. Further research efforts are directed towards a better understanding of similar mechanisms in the Northern Hemisphere.

References

Brandefelt, J. and Källén, E. 2004. The response of the Southern Hemisphere atmospheric circulation to an enhanced radiative forcing. Journal of Climate, 17, 4425-4442

Aerosols, clouds and global climate

Henning Rodhe, Frida Bender, R. J. Charlson and T. Anderson (University of Washington, Seattle) in collaboration with several others

The objectives of this project are to estimate the impact of aerosols and clouds on global climate and to identify possible negative (stabilizing) feedbacks in the climate system. The relative stability of global temperature climate during Holocene strongly suggests that such negative feedbacks operate in the climate system. In view of their strong impact on global albedo, it is also very likely that clouds play an important role in such feedback processes. Analysis of output from GCMs (clouds, albedo etc) and of satellite observations will be the main activities of this project.

References

Anderson, T.L., Charlson, R.J., Schwartz, S.E., Knutti, R., Boucher, O., Rodhe, H. and Heintzenberg, J. 2003. Climate Forcing by Aerosols – a Hazy Picture. Science, 300, 1103-1104

Anderson, T. L., Charlson, R. J., Schwartz, S. E., Knutti, R., Boucher, O., Rodhe, H. and Heintzenberg, J. 2003. Response to "The parasol effect on climate" by P. J. Crutzen and V. Ramanathan. Science, 302, 1680-1681

Ensemble prediction systems

Thorsten Mauritsen, Tomas Mårtensson, Erland Källén

Ensemble numerical weather prediction is performed at the main numerical weather prediction centres through a technique where initial state perturbations are constructed to ensure that the forecast ensemble spread is as large as possible given the actual flow situation. One technique is based on the use of singular vectors, the perturbations are designed to optimise growth within the first 48 hours of the forecast. In an idealised study we have shown that singular vector perturbations are very dependent on the optimisation time interval, a better measure of the instability of the flow appears to be a classical Eady index that mainly reflects the local strength of the thermal wind. To investigate the relation between localised amplitudes of singular vectors and the Eady index a set of ensemble forecasts from ECMWF have been analysed. It is found that the Eady index gives some indication of the forecast ensemble spread.

Another aspect of ensemble forecasting is the relation between large scale flow instabilities and ensemble spread. To determine if the blocking phenomenon has any relation to long wave instabilities associated with topographic drag, a set of ECMWF ensemble forecasts have been analysed using a blocking index as a sorting parameter. It is found that the ensemble spread is large in situations where the large scale flow regime is entering a blocked flow situation while it is smaller in situations where blocks have been established. This result lends support to so called multiple equilibria theories that explain why blocked or non-blocked flows may persist under unchanged external conditions. Which type of flow that dominates is only dependent on the initial conditions.

References

Mauritsen, T. and Källén. E, 2004. Blocking prediction in an ensemble forecasting system. Tellus, 56A, 218-228

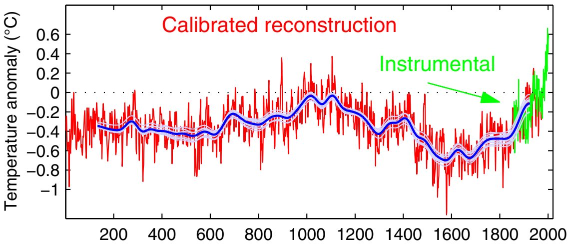
Mårtensson, T. 2004. Singular vector growth over short time scales. MISU-DM report no 92, pp 41

A 2000-year temperature reconstruction for the northern hemisphere

Anders Moberg, Karin Holmgren and Wibjörn Karlén (Dept. of Physical Geography and Quaternary Geology, Stockholm University), Dmitry M. Sonechkin and Nina M. Datsenko (Hydrometeorological Research Centre of Russia)

A number of reconstructions of millennial-scale climate variability have previously been carried out in order to understand patterns of natural climate variability, on decade to century timescales, and the role of anthropogenic forcing. These reconstructions have mainly used tree-ring data and other data sets of annual to decadal resolution. Lake and ocean sediments have a lower time resolution, but provide climate information at multicentennial timescales that may not be captured by tree-ring data. We have reconstructed Northern Hemisphere temperatures for the past 2,000 years by combining low-resolution proxies with tree-ring data, using a wavelet transform technique to achieve timescale-dependent processing of the data such that tree-ring data are used to reconstruct variability at <80-yr timescales and the low-resolution data for the >80-yr timescales.

Our reconstruction shows larger multicentennial variability than most previous multi-proxy reconstructions, but agrees well with temperatures reconstructed from borehole measurements and with temperatures obtained with a general circulation model run with reconstructed radiative forcing due to solar irradiance changes, volcanic aerosols and greenhouse gases. According to our reconstruction, high temperatures – similar to those observed in the twentieth century before 1990 – occurred around AD 1000 to 1100, and minimum temperatures that are about 0.7 K below the average of 1961–90 occurred around AD 1600. Our findings underscore a need to improve scenarios for future climate change by also including forced natural variability which could either amplify or attenuate anthropogenic climate change significantly.



Northern Hemisphere temperatures

References

Moberg, A., Sonechkin, D.M., Holmgren, K., Datsenko, N.M. and Karlén, W. 2005. Highly variable Northern Hemisphere temperatures reconstructed from low- and high-resolution proxy data. Nature, 433: 613-617, doi:10.1038/nature03265

Impact of large-scale dynamic changes on Arctic climate

Rune Grand Graverssen, Michael Tjernström and Erland Källèn

See Arctic Studies

ADDITIONAL PUBLICATIONS: DYNAMIC METEOROLOGY

Rummukainen, M., S. Bergström, G. Persson, J. Rodhe and M. Tjernström. 2004. The Swedish regional climate modelling programme, SWECLIM. AMBIO, 33, 176-182

Tjernström, M. and Anna Rune. 2003. The turbulence structure of stratocumulus during the ASTEX first Lagrangian experiment. Quarterly Journal of the Royal Meteorological Society, 129, 1071-1100

PHYSICAL OCEANOGRAPHY

The activities of the physical oceanographers at MISU can, in general terms, be described as focusing on two main topics: (i) large-scale global processes of direct relevance for climatological research, and (ii) more-or-less local investigations with emphasis on conditions in the Baltic. Among the former research themes the global thermohaline circulation constitutes a key issue. This problem, with emphasis on the manifestations of the THC in the North Atlantic/Nordic Seas is being dealt with on the basis of numerical modelling, satellite-altimetric analyses and field investigations (the latter conducted in the form of collaborative international efforts). This larger-scale research also comprises more detailed process studies focusing on the role of internal-wave motion for oceanic mixing as well as geobiochemically orientated investigations of gas exchange at the air-sea interface. The Baltic research deals with the surface- and deep-water circulation and their effects on dispersion. These investigations are mainly being carried out on the basis of numerical modelling, but it is also worth underlining that a novel geoelectric observational system is being maintained to monitor the main circulation gyre of the Baltic proper.

Deep-water transports from the Nordic Seas to the North Atlantic

Peter Lundberg in external collaboration with K. Borenäs/I. Lake at SMHI and A. Nikolopoulos at Woods Hole Oceanographic Institution

The deep-water transport across the Greenland-Scotland Ridge constitutes an important link in the global thermohaline circulation. The most important overflows take place through the Denmark Strait and the Faroe-Bank Channel. On the basis of ongoing field studies of these two passages, hydraulic investigations of the transports and their forcing mechanisms have been undertaken with encouraging results. Of particular interest is the result that the nonuniform potential vorticity characterizing the deep-water flow through the Faroe-Bank Channel does not appear to affect the overflow process in any significant way.

References

Borenäs, K. and P. Lundberg. 2004. The Faroe-Bank Channel deep-water overflow, Deep-Sea Res. II 51, 335-350

Lake, I., K. Borenäs and P. Lundberg. 2004.Potential-vorticity characteristics of the Faroe-Bank Channel deep-water overflow, J. Phys. Oceanogr. (In Press)

Nikolopulos, A., K. Borenäs, R. Hietala and P. Lundberg. 2003. Hydraulic estimates of the Denmark Strait overflow. J. Geophys. Res. 108(C3) 3095, doi:10.1029/2001JC001283

Transports and dispersion in the Baltic

K. Döös, B. Jönsson, P. Lundberg, Jenny Nilsson and P. Sigray in external collaboration with O. Andreev/K. Myrberg at the Finnish Institute of Marine Research, Helsinki and R. Döscher/M. Meier at SMHI

The large-scale circulation as well as dispersion in this for Sweden very important water body is being examined on the basis of numerical modelling as well as field studies using motionally induced voltages. Interest has particularly been focused on the transect Visby-Västervik, where a telecommunications link is employed for the voltage monitoring. The dispersion studies mainly dealing with the Gulf of Riga and the Bay of Gdansk have been undertaken using analysis of trajectories originating from the RCO model, whereas the investigations of the Gulf of Finland have been based on a model run by the Finnish Institute of Marine Research.

References

Andreev, O., K. Myrberg, P. Alenius and P. Lundberg. 2003. Mean circulation and water exchange in the Gulf of Finland – a study based on three-dimensional modeling. Boreal Env. Res. 9, 1-16

Andreev, O., K. Myrberg and P. Lundberg. 2004. Age and renewal time of water masses in a semi-enclosed basin – application to the Gulf of Finland. Tellus 56A, 548–558

Döös, K., M. Meier and R. Döscher. 2004. The Baltic Haline conveyor belt or the overturning circulation in the Baltic, Ambio 33, 261-266

Jönsson, B., P. Lundberg and K. Döös. 2004. Baltic sub-basin turnover times examined using the Rossby Centre ocean model, Ambio 33, 257-260

Sigray, P. and P. Lundberg. 2004. A new method for monitoring long-term transport variability in the Baltic. Ambio 33, 267-274

Sigray, P., P. Lundberg and K. Döös. 2004. Observations of transport variability in the Baltic Sea by parasitic use of a fiber-optic cable. J. Atmos. Ocean. Technol. 21, 1112-1120

Deep-water transports in the Baltic

P. Lundberg in external collaboration with K. Borenäs at SMHI, R. Hietala at the Finnish institute of Marine Research, Helsinki and J. Laanearu at the Estonian Technical University, Tallinn

The deep-water transports between the various well-delimited deep basins of the Baltic are crucial for the deep-water renewal, which in turn plays an essential role for the maintenance of biological production. Based on rotating hydraulic theory the deep-water flows through Irbe Strait (connecting the Gulf of Riga with the Baltic proper) and the Bornholm Channel have previously been examined and analysed. Work is presently being focused on the Stolpe Channel connecting the Bornholm and Gdansk Basins and the Understen-Märket passage between the Sea of Åland and the Bothnian Sea.

References

Laanearu, J. and P. Lundberg. 2003. Topographically constrained deep-water flows in the Baltic Sea. J. Sea Res. 49, 257-266

Laanearu, J. and P. Lundberg. 2004. Analysis and improvement of a perturbative solution for hydraulic flow in a rotating parabolic channel. ZAMM (In Press)

The Atlantic inflow to the Norwegian Sea

K. Döös, P. Lundberg, Johan Nilsson, R. Mohammad and P. Sigray

This climatologically important process is being studied using both motionally induced voltages and satellite altimetry. The voltage-monitoring installation (based on the Faroese branchline to the transatlantic CANTAT cable running north of the islands) has been operational since early 2002 and has already yielded some interesting and encouraging results. Fig. A thus shows the monitored voltage from 9/4 2002 to 14/6 2003 as well as transport estimates of the Iceland-Faroes branch of the Atlantic inflow to the Norwegian Sea based on ADCP records from a transect in the immediate vicinity of the cable. There is evidently a relationship between these two independently monitored quantities, which is being further investigated on the basis of a comparison between the voltage-monitored tidal currents and those modelled using the standard Oregon tidal model, cf. Fig. B. The forthcoming calibration of the cable-voltage results will thus be based on physical first principles rather than on an empirically determined proportionality (as has been the case for many other cable installations).

The altimetric investigations are based on a merged data set from six different satellites. Due to the nature of the altimetric data, focus is on the SSH anomalies, particularly the winter-to-summer difference. Interest has hitherto primarily been directed towards conditions in the southern Norwegian Sea, which has lead to the interesting result that the observed seasonal variation of the Norwegian Sea Deep Water outflow through the Faroe-Bank Channel is barotropically induced by the surface-layer Atlantic inflow.

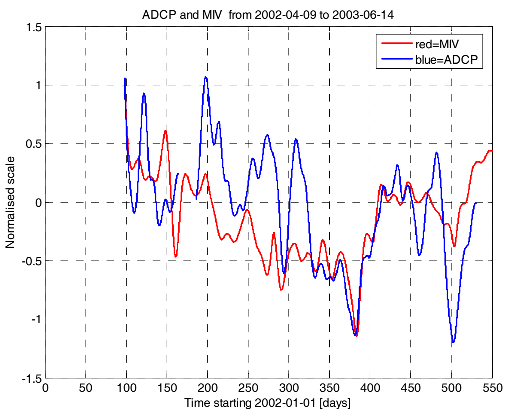


Fig. A: Comparison between the observed induced voltage across the Faroese branch-line to the transatlantic CANTAT cable and transport estimates based on ADCP records. The results span the period 9/4 2002 – 14/6 2003 and have been low-pass filtered with a cut-off at 20 days.

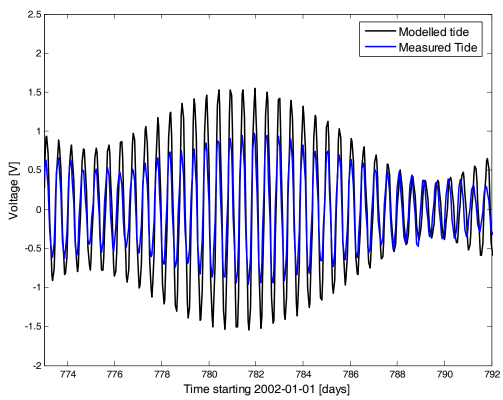


Fig. B: High-frequency voltage records displaying the main semi-diurnal moon tide which dominates in the area and the transport results calculated from the Oregon tidal model. These two independently determined quantities are used to calibrate the long-term cable-voltage results.

The role of the sea surface waves for the mass transport in the upper ocean

Göran Broström, in external collaboration with J. E. Weber (Oslo University) and K. Christensen (Göteborg Univ.)

It is well known that sea surface waves possess a certain momentum in the direction of the wave propagation; this momentum is also visible as a mass transport in the upper ocean. Although the equations describing the wave motions are well known, the mathematical complexity of correctly describing the undulating sea surface still restricts the usability of these theories in a geophysical context. Presently we evaluate two different mathematical approaches to describe the mass transport; namely, a Lagrangian approach where the undulating sea surface is described in natural coordinates and an integrated Eulerian approach where the entire mass transport of the upper ocean is described in a fairly simple way. The complexity of the wave-mean flow interaction implies that an inter-comparison between various theories is necessary to pave the way for studies of more complex situations.

The role of the annual cycles for the air-sea gas exchange with special reference to the carbon cycle

Göran Broström, in external collaboration with Stephanie Dutkiewicz (MIT, USA), Michael Follows (MIT, USA), and Raymond Sambrotto (Columbia University, USA)

The ocean plays a crucial role in the global scale biogeochemistry cycle due to the large gas exchange between the ocean and the atmosphere. There is a strong seasonality in these fluxes due to shallow mixing conditions in the ocean during summer creating both a strong biological productivity and trapping the air-sea flux of gases within a shallow layer. It may be shown that the shallow mixing conditions during summer may act as a resistance for slowly equilibrating gases such as carbon dioxide while very fast (i.e, oxygen) and very slow equilibrating gases (i.e., ^{14}C) are not influence by the annual mixing cycle. For paloeclimate studies various types of gases are used to calibrate models; thus, a proper description of the role of the seasonal cycle must be considered for precise understanding of changes in the chemical cycle between glacial and inter-glacial periods.

References

Broström, G. 2004. On the relation between total inorganic carbonate concentration and temperature in the winter mixed layer of the northern North Atlantic. Tellus, 56B, 72-84

The global thermohaline circulation and climate change

Göran Broström, Rezwan Mohammad and Johan Nilsson, in external collaboration with Joe LaCasce (Oslo University), Jeff Scott (MIT) and Gösta Walin (Göteborg University)

This project explores the dynamics of the global thermohaline circulation, emphasizing its stability and response to altered surface buoyancy forcing. In particular, two processes of relevance for the stability of the "Gulfstream circulation" in the northern North Atlantic are examined. First, the possibility that the high-latitude branch of the thermohaline circulation has a strong barotropic component, driven non-locally by bottom anomalies of density on the continental slopes in the lower latitudes. Secondly, feedbacks on the large-scale circulation arising from a dependence of the small-scale vertical mixing on the stratification of the water column. Results from ocean-circulation modelling, employing idealized basin geometry, demonstrate that these two processes generally serve to stabilize the thermohaline circulation.

References

Nilsson, J., G. Broström, and G. Walin. 2003. The thermohaline circulation and vertical mixing: Does weaker density stratification yield stronger overturning? J. Phys. Oceanogr., 33, 2781-2795

Mohammad, R., and J. Nilsson. 2004. The role of diapycnal mixing for the equilibrium response of thermohaline circulation. Ocean Dynamics, 54, 54-65

Nilsson, J., G. Broström and G. Walin. 2004. On the spontaneous transition to asymmetric thermohaline circulation. Tellus, 56A, 68-78

Walin, G., G. Broström, J. Nilsson and O. Dahl. 2004. Baroclinic boundary currents with downstream decreasing buoyancy; a study of an idealized Nordic Seas system. J. Mar. Res., 62, 517-543

Existence proofs for stable flows by variational principle

Jonas Nycander, in external collaboration with Joseph LaCasce (DNMI), Behrouz Emamizadeh (Inst. For Theoretic Physics, Iran), Fariba Bahrami (Tabriz University, Iran)

According to a fundamental variational principle, a flow that maximizes or minimizes the energy in a set of isovortical flows is stationary and stable. For example, in ideal, two-dimensional flow, a circular vortex with a monotonic vorticity profile is a maximum energy flow, and therefore stable. This principle can be applied to oceanic flows above nonuniform topography. In this way it has been shown that a large class of anticyclonic vortices exists that are attached to a given localized seamount of arbitrary shape. If the seamount is circular there are also stable cyclones, but these are destabilized by noncircularities in the topographic shape, unlike the anticyclones. Future work will involve basin-scale flows, with possible applications to the circulation in the Nordic Seas.

Generation of internal waves in the ocean by tides

Jonas Nycander

While the atmosphere can be regarded as a heat engine, the ocean circulation is driven mechanically by winds and tides. In the upper 1000 m of the ocean the winds play a dominating role, but below this the tides are important. When tidal currents encounter rough topography on the bottom of the ocean, internal waves are generated. As these waves steepen and break, they cause the vertical mixing that drives the deep circulation.

The energy flux from tides to internal waves has been computed over the global ocean. The method is based on linear wave theory, and involves the computation of a convolution integral, thus taking the nonlocality of the wave generation process into account. The input data were a global satellite-based bottom topography with a nominal resolution of 1/30 degrees, the tidal velocity from a tidal model, and the buoyancy frequency from a global hydrographic database. The flux density was obtained with the same horizontal resolution as the topography. The globally integrated energy flux agrees well with independent estimates of the tidal dissipation based on inverse calculations using satellite altimeter data. The main uncertainties of the computation are due to unresolved topography, and to the effect of supercritical topographic slopes, for which this linear calculation is invalid. In future work the results will be compared with measured dissipation data, and the effect of supercritical slope will be investigated in detail.

Meridional overturning in the Southern Ocean

Kristofer Döös, Jonas Nycander in external collaboration with Andrew Coward (Southampton Oceanography Centre, UK)

The global world ocean circulation can not be visualised in one single figure because it is three dimensional in space and changes in time. For this reason one can or choose to look at a particular place or one can try to capture most of the circulation by making an average. The meridional overturning stream function is one of the most common simplifications of the meridional-vertical circulation, which it makes it possible to capture a large part of both the world thermohaline circulation and the wind driven circulation. It is based on zonal average on of the meridional velocity over an entire basin or as in the atmosphere all around the world.

The meridional overturning cells in the Southern Ocean are decomposed by Lagrangian tracing. Particular emphasis is given to the Deacon Cell. The flow is divided into four major components: 1) Circling water around Antarctica in the Antarctic Circumpolar Current (ACC), 2) water leaving the ACC towards the north into the three world oceans, 3) water coming from the north and joining the ACC which, mainly consists of North Atlantic Deep Water (NADW) and 4) inter-ocean exchange between the three world oceans without circling around Antarctica. The Deacon cell can be explained by the superposition of the ACC and the sub-tropical gyre.

The bolus effect of the Deacon cell is calculated from different time averaging of meridional overturning stream function as a function of density. Only 3 Sv out of 11 Sv of the Deacon cell is true diapycnal. The rest can be explained by the temporal variability of the density field and the velocity field not being in "phase". This so called bolus effect arises when the overturning stream function as a function of density is calculated from the zonal integration of the time averaged velocity field along the time averaged density layers. Most of the Deacon cell vanishes when the time average is instead made over the all ready calculated stream function for the individual "snap shots". The time scale of the bolus effect of the Deacon cell is estimated by making time average over time periods from 5 days to 12 years. The effect drops exponentially in time with an e-folding decay time of around 60 days.

Nordic Seas 2002; a scientific synthesis of the field experiment conducted from the R V Knorr and the ice-breaker Oden April to June 2002

Johan Nilsson, in external collaboration with Göran Björk (Göteborg University), Bert Rudels (Finnish Marine Research Institute) and Peter Winsor (Woods Hole Oceanographic Institution)

See Arctic Studies

The properties of the surface microlayer of the open leads and the ocean mixed layer in the central arctic basin pack ice area

Caroline Leck, Keith Bigg, Patricia Matrai, Johannes Knulst, Kalle Olli, Lars Tranvik, Paul Wassman and Johanna Ikavälko

See Arctic Studies

CHEMICAL METEOROLOGY

The research in chemical meteorology involves studies of the occurrence and transfer of chemical species in the atmosphere as dependent on meteorological conditions: winds, clouds, precipitation etc. This is done by measuring the chemical composition of air, aerosols, cloudwater and precipitation and by theoretical modelling of transport, transformation and removal processes. The main focus is on the biogeochemical cycling, on regional and global scales, of constituents containing sulfur (SO_2, DMS, SO_4^{2-}), nitrogen (NO_x, HNO_3, NO_{3-}) and carbon (elemental carbon, hydrocarbons). The study of biogeochemical cycles requires special attention to exchange processes between the atmosphere and the oceans and between the atmosphere and the soil/vegetation system. It is therefore essential to maintain close cooperation with marine and terrestrial ecologists and oceanographers. Several of the projects are motivated by concern about the effects of anthropogenic impact on the chemical composition of the atmosphere: acidification, human impact on climate and excessive amounts of ozone in the lower troposphere. The specific research areas include:

- PRECIPITATION CHEMISTRY
- AEROSOLS AND REACTIVE TRACE GASES
- MODELLING OF TROPOSPHERIC CHEMISTRY

PRECIPITATION CHEMISTRY

Composition of Asian Deposition (CAD)

Lennart Granat, Henning Rodhe, Michael Norman, Leong Chow Peng (Malaysian Meteorological Institute), R. Bala (University of Singapore), P.S.P. Rao and A.G. Pillai (Indian Institute of Tropical Meteorology, Pune, India), P.Gupta (National Physical Laboratory, Delhi), S.N. Das and R.S. Tharkur (Regional Research Laboratory, Bhubaneswar, India)

The purpose of this project is to estimate the wet and dry deposition of biogeochemically important trace species, including sulfur and nitrogen compounds, calcium, sodium, chloride etc., to terrestrial ecosystems in S and SE Asia. Wet deposition is measured using both bulk and wet-only samplers and dry deposition is estimated from measurements of the concentration of gaseous and aerosol components in surface air. The project is funded by the Swedish International Development Co-operation Authority (Sida) through the Regional Air Pollution in Developing Countries (RAPIDC), program which is co-ordinated by the Stockholm Environment Institute (SEI). The focus of CAD is on rural areas such that the data can also be used in studies of regional transport of air pollutants.

Two genuinely rural stations in eastern and western India, respectively, are now running in co-operation with RRL and IITM. Wet deposition at the station in eastern India is about neutral in terms of acidification (pH is about 5.5), but since ammonium is the major cat-ion the composition may lead to acidification in the soil due to ecosystem processes. The western part of India receives more carbonate and less ammonium and here the wet deposition is still alkaline despite increase in anthropogenic emission of acidifying components. An analysis of rain chemistry data with the aid of trajectories showed that pH and ionic concentrations vary systematically with the origin of the air and amount of rainfall along the trajectory.

References

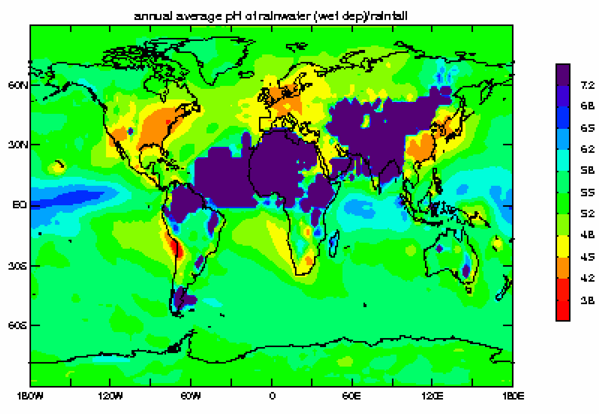
Kulshrestha, U.C., Granat, L. and Rodhe, H. 2003. Precipitation chemistry studies in India – a search for regional patterns. Report CM-99, Department of Meteorology, Stockholm University and International Meteorology in Stockholm. 58 pp

The global distribution of acidifying wet deposition and ecosystem sensitivity

Henning Rodhe, J.C. Kuylenstierna and K Hicks (Stockholm Environment Institute, York, UK), Frank Dentener (Joint Research Institute, Ispra, Italy), Michael Schulz (Lab. des Sciences du Climat, Gif-sur-Yvette, France)

The acid-base status of precipitation is a result of a balance between acidifying compounds – mainly oxides of sulfur and nitrogen – and alkaline compounds – mainly ammonia and alkaline material in windblown soil dust. We use current models of the global atmospheric distribution of such compounds to estimate the geographical distribution of pH in precipitation (c.f. Figure) and of the rate of deposition of hydrogen ion or bicarbonate ion. The lowest pH values – mainly due to high concentration of sulfuric acid – occur in eastern parts of North America, Europe, and China. A comparison with observed pH values shows fair agreement in most parts of the world. However, in some areas, e.g. western North America, south-western Europe, and northern China the estimated pH is too low, indicating that we have underestimated the deposition flux of alkaline material, probably mainly $CaCO_3$. Potential problem areas for the future soil acidification include several regions with sensitive soils in southern, south-eastern, and eastern Asia as well as in central parts of South America.

A methodology investigating the extent of acidification risks from sulfur and nitrogen emissions on a global scale is being developed. Atmospheric transfer models have been used to calculate transfer and deposition of sulfur, nitrogen and alkaline soil dust. A method to derive the relative sensitivity of terrestrial ecosystems is explained and preliminary critical load values have been assigned. These show an increasing risk of acidification in 2050 in some regions of southern and eastern Asia, as well as parts of southern Africa, in comparison to 1990.



Model estimate of the annual average pH of precipitation.

References

Rodhe, H., Dentener, F. and Schulz, M. 2002. The global distribution of acidifying wet depositions. Environ. Sci. Technol. 36, 4382-4388

Atmospheric Brown Cloud (ABC) – Asia

Caroline Leck, Henning Rodhe, Lennart Granat, Erik Engström, J. Heintzenberg (Institute for Tropospheric Research, Leipzig, Germany), U.Kulshrestha (Indian Institute of Chemical Technology, Hyderabad), P.S.P. Rao (Indian Institute of Tropical Meteorology, Pune, India)

The international ABC (www-abc-asia.ucsd.edu) project has been launched in response to the dramatic results obtained during the INDOEX project regarding transport of highly polluted air from the Asian continent out over the Indian Ocean during the winter monsoon season. As a first step observatories will be set up in the S and SE Asian region to monitor the concentration of pollutants and their impact on the radiation balance of the atmosphere. The major scientific objectives of the observatories are:

- To establish continuous chemical and microphysical aerosol observations at key locations in the Indo-Asian-Pacific region with a particular emphasis on black carbon, organics and cloud condensation nuclei. A major thrust of these observatories will be characterization of the sources of these aerosols based on the analysis of aerosol filters for molecular markers and single particle analysis. The identified sources from the molecular markers will include bio-fuels and other forms of biomass burning; coal combustion; diesel and two-stroke engines. The source characterization will be used by UNEP and the regional governments to develop future strategies to mitigate the impact of Asian air pollution on climate, human health, and the environment.

- To use regional scale source-receptor models in conjunction with the data from observatories and validated satellites to identify the relative contribution of the various Asian regions to the observed aerosol loading.
- To determine direct short-wave and long-wave aerosol radiative forcing at the surface and top of the atmosphere based on aerosol data in conjunction with comprehensive in situ and remote radiometric measurements.
- To relate the aerosol forcing to regional sources of aerosol emissions. The ABC project will also include studies of the effects of the pollutants on human health and on agriculture. Capacity building and dialogue with policy makers will be important components.
- The main MISU/IMI contribution to ABC is to measure the chemical composition of aerosols and precipitation – with a focus on black carbon and various organic and inorganic components – at four sites in S Asia: Maldives, Nepal, Pune (India) and Andaman Island (India).

AEROSOLS AND REACTIVE TRACE GASES

Distribution of marine boundary layer ammonia over the Atlantic and Indian oceans

Caroline Leck and Michael Norman

In maritime air a substantial fraction of the acid particles appears to be at least partly neutralized by a gas phase reaction with ammonia (NH_3). As a consequence NH_3 influences the chemical and physical properties of aerosol particles linked to clouds and climate. The Aerosols99 cruise, January to February 1999, from Norfolk (USA) to Mauritius gave us the opportunity to measure atmospheric NH_3 concentrations in the marine boundary layer (MBL) over the Atlantic Ocean and southern Indian Ocean.

An overall large variation in gas phase NH_3 was encountered with peak values occurring in regions heavily influenced by the smoke plume from biomass combustion and dust sources on the African continent. Concentration showed typically in the range 7 to 22 nmolm^{-3}.

Within the remote MBL over the South Atlantic and Indian Oceans median NH_3 concentrations ranged between 1.1 and 3.2 nmol m^{-3}. It was reasonable to assume that the ocean was a net emitter of NH_3 to the atmosphere and thus responsible for the NH_3 levels measured. An average residence time of the order of a few hours was estimated. One implication of such rapid removal of NH_3 is that it prevented equilibrium to exist between the gas phase and particulate phase ammonium. On the contrary, areas under influence of African biomass burning or dust, the particulate phase ammonium was concluded to be in equilibrium with the gas phase NH_3.

The removal of atmospheric NH_3 during the time of travel from the African continent to the position of the ship was estimated using a simplified Lagrangian approach. A response or residence time of 20 to 130 hours resulted. Thus in order to explain the observed atmospheric NH_3 levels at the ship it seemed necessary to allow for an NH_3 residence time of the order of several days within the plume which largely differs from previous reported estimates.

The Indian Ocean Experiment (INDOEX)

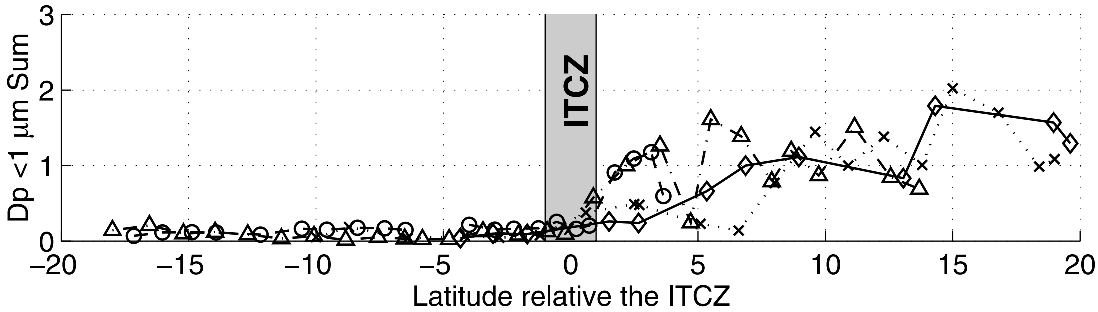
Mikael Norman, Caroline Leck, Lennart Granat, Henning Rodhe, U. Kulshrestha (Indian Institute of Chemical Technology, Hyderabad)

The water soluble part of the sub-micrometer aerosol and rainwater was measured from two research vessels over the Indian Ocean during the winter monsoon season (February and March) as part of the Indian Ocean Experiment (INDOEX) in 1998 and 1999. Additional measurements were made of gas phase SO_2 from one of the vessels in 1999. We found the Inter-Tropical Convergence zone (ITCZ) to be an effective barrier for sub-micrometer particles in the marine boundary layer with no indication of transport across the ITCZ. Irrespective of the latitudinal position all samples collected north of the ITCZ were clearly affected by continental, anthropogenic sources in India or surrounding land areas. A sharp transition occurred across the ITCZ with concentrations of total analyzed mass, nss-SO_4^{2-}, NH_4^+ and nss-K^+ being lower by a factor of 6-14, 7-15, >20 and >40, respectively, on the southern side of the ITCZ, c.f. figure below. There was no, or only marginal, influence of continental or anthropogenic nss-SO_4^{2-} south of the ITCZ and the variation in concentration was attributed to variation in the marine biogenic sources. Surprisingly, MSA, which is derived from DMS, also showed higher concentrations in the submicrometer aerosol north of the ITCZ than south of it. This could be explained by the larger submicrometer surface area available north of the ITCZ for the condensation of MSA. The acidity of the rainwater over the Indian Ocean was higher (pH on the range 4.8 to 5.3) than over the Indian subcontinent.

References

Granat, L., Norman, M., Leck, C., Kulshrestha, U. C. and Rodhe, H. 2002. Wet scavenging of sulfur compounds and other constituents during the Indian Ocean Experiment. J. Geophys. Res. – Atmos., 107 (D19): Art. No. 8025, doi: 10.1029/2001JD000499

Norman, M., Leck, C. and Rodhe, H. 2003. Differences across the ITCZ in the chemical characteristics of the Indian Ocean MBL aerosol during INDOEX. Atmos. Chem. Phys., 3, 563-579



The concentration of total analyzed water-soluble submicrometer aerosol during four cross ITCZ passages as a function of the latitude relative to the ITCZ. The concentrations are normalized to the median concentration north of the ITCZ for each passage.

Baseline measurements of airborn particles at Tasmania

Caroline Leck and Jost Heintzenberg (Institute for Tropospheric Research, Leipzig, Germany)

A long-term soot-sampling program in collaboration with the Australian baseline station is in operation at Cape Grim, Tasmania since 1982. A second time series with modified sample substrate was started in 1991, one year before the supply of the first type of substrate was exhausted. On the second substrate, major ions have been analyzed for complementary aerosol chemical information and for systematic corrections of the optical soot measurements.

At the Cape Grim station a host of meteorological and trace substance information is available for the interpretation of aerosol data in terms of natural and anthropogenic sources, local regional and long-range influence. The combined ancillary information has been used to harmonize the two parts of this unique time series of an anthropogenic aerosol component.

Beyond a previous interpretation that had identified southern African biomass burning as dominating the seasonal soot cycle at Cape Grim, long-term trends in regional pollution and transport patterns are suggested to be of great importance for the temporal evolution of the 20-year long soot record.

Determination of amino acids, proteins and other organic compounds in aerosol specimens

Bodil Widell and Caroline Leck

The influence of organic components of the atmospheric aerosol on the concentration of cloud condensation nuclei (CCN) has recently demonstrated to make a potentially important contribution to the aerosol-cloud-climate system. To obtain quantitative information of the organic components present in the aerosol, one approach is to use size-segregated bulk-chemical mass detection. The advantage with such an approach is that a quantitative determination of a wide spectrum of organic water-soluble and -insoluble organic components is made possible. The disadvantages are that the organic constituents could not be determined in individual particles and that the determination is confined to particles in the volume/mass range that is to sizes larger than 100 nm diameters.

The method described was specifically designed to determine the aerosol content of amino acids and proteins. Size-segregated (diameter 100nm to 10000nm) aerosol mass was collected on Tedlar film-substrates using a high volume Berner impactor followed by an extraction using repeated applications of methanol. The extract was rinsed through a column packed with a cation exchange phase for further isolation of the amino acids and proteins.

For the analyses of non-volatile and polar substances such as amino acids the compouns have to be chemically and/or physically modified before they can be separated on a GC (Gas Chromatograph) column. In this method they were silylated with N-methyl-N-tert-butyldimethylsilyl-trifluoroacetamide (MTBSTFA). Polar hydrogens, -OH, -SH or -NH, were replaced with tertbutyl-dimethylsilyl (TBDMS) groups which will decrease the capacity for the compounds to bind irreversible to the column wall. The derivates were determined by a High Resolution GC coupled to a High Resolution Mass detector (HRGC-HRMS), r.p. 10 000. All steps in the method will be optimized due to recoveries with commercial amino acid standards and thereafter be applied to samples collected north of 80° during an icebreaker expedition in the summer of 2001.

Arctic study of tropospheric aerosols, clouds and radiation (ASTAR 2004)

Radovan Krejci, Ann-Christine Julin, Thorsten Mauritsen, Gunilla Svensson, A. Herber and O. Schrems (Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven, Germany), R. Treffeisen, R. Neuber, C. Ritter and K. Hara (Alfred-Wegener-Institut für Polar- und Meeresforschung, Potsdam, Germany), T. Yamanouchi (National Institute for Polar Research, Tokyo, Japan), J. Ström (ITM – Air Pollution Laboratory, Stockholm University), S. Yamagata (Hokkaido University, Graduate School of Engineering, Sapporo, Japan), A. Minkin (German Aerospace Center, Institute for Physic of Atmosphere, Wessling, Germany), A. Schwarzenboeck and J.F. Gayet (Université Blaise Pascal/CNRS, France)

See Arctic Studies

Biogenic particles over the central Arctic Ocean

Caroline Leck and Keith Bigg

See Arctic Studies

New evidence of fog-related aerosol sources over the arctic pack ice in summer

Jost Heintzenberg, Caroline Leck and Michael Tjernström

See Arctic Studies

Evidence of a surface source of ultra fine aerosol particles in the Arctic Ocean pack ice during summer

Caroline Leck, Keith Bigg, Erik Swietlicki and Michael Tjernström

See Arctic Studies

Importance of submicrone surface active organic aerosols for pristine Arctic clouds – a model study

Ulrike Lohmann and Caroline Leck

See Arctic Studies

MODELLING OF TROPOSPHERIC CHEMISTRY

Simulations of aerosol-cloud interaction in deep convective clouds

Annica Ekman, Chien Wang (EAPS, MIT, Cambridge, USA)

Convective clouds have been recognized as an important mechanism for transferring chemical compounds from the surface to the free troposphere. Several observations have also indicated high number concentrations of small aerosols in the vicinity of the anvils of convective clouds. One theory has been that the environment in this area is favorable for nucleation of particles as both the relative humidity and the concentration of aerosol precursors are relatively high. Another explanation for the small aerosols found near the top of convective clouds could be direct transport from the surface to the free troposphere by strong vertical updrafts. However, a great number of aerosols are water soluble and/or effective as cloud condensation nuclei (CCN) and are hence likely to be scavenged by the heavy precipitation. In addition, aerosols in the free troposphere can serve as ice nuclei and thus likely to be scavenged through the formation of ice clouds.

In this research project, an interactive aerosol-cloud-resolving model has been developed and utilized to study formation, transport and growth of aerosols within convective clouds. The aim is also to study the interaction of aerosols with cloud droplets and ice particles. An evaluation of the model versus aircraft measurements shows good agreement between model and observations for average values and variability of meteorological and chemical variables.

Using the model, it is concluded that up to 10% of the surface concentration of small/middle size sulfate aerosols (5.84 nm$\leq$ d $\leq$31.0 nm) may reach the free troposphere. An approximately equal amount of hydrophobic aerosols (black carbon) are also transported from the surface to the cloud anvil. There is some formation of nucleation mode aerosols (d $\leq$5.84nm) occurring within the convective cloud but these aerosols are quickly deposited on the larger ones, or scavenged by falling precipitation. Accumulation mode aerosols (d $\geq$31.0nm) are efficiently used as CCN and are hence completely scavenged within the convective cloud.

References

Ekman, A.M.L. and Rodhe, H. 2003. Regional temperature response due to indirect sulfate aerosol forcing: Impact of model resolution. Clim. Dynam., 21, 1-10, doi:10.1007/s00382-003-0311-y

Ekman, A., Wang, C., Wilson, J. and Ström, J. 2004. Explicit simulations of aerosol physics in a cloud-resolving model: A sensitivity study based on an observed convective cloud. Atmospheric Chemistry and Physics, 773-791

Atmospheric dust during LGM

M. Werner, C. Roelandt, I. Tegen, S.P. Harrison, K.E. Kohfield, I.C. Prentice (Max Planck Institute for Biogeochemistry, Jena, Germany), Henning Rodhe, T. Claquin, Y. Balkanski (Lab. des Sciences du Climat, Gif-sur-Yvette, France), Margareta Hansson (Dept. Physical Geography and Quaternary Geology, Stockholm University)

During glacial periods, dust deposition rates and inferred atmospheric concentrations were globally much higher than present. According to recent model results, the large enhancement of atmospheric dust content at the last glacial maximum (LGM) can be explained only if increases in the potential dust source areas are taken into account. Such increases are to be expected, due to effects of low precipitation and low atmospheric (CO_2) on plant growth. Here the modelled three-dimensional dust fields from Mahowald et al. and modelled seasonally varying surface-albedo fields derived in a parallel manner, are used to quantify the mean radiative forcing due to modern (non-anthropogenic) and LGM dust. The effect of mineralogical provenance on the radiative properties of the dust is taken into account, as is the range of optical properties associated with uncertainties about the mixing state of the dust particles. The high-latitude (poleward of 45°) mean change in forcing (LGM minus modern) is estimated to be small (-0.9 to +0.2 W m^{-2}), especially when compared to nearly -20 W m^{-2} due to reflection from the extended ice sheets. Although the net effect of dust over ice sheets is a positive forcing (warming), much of the simulated high-latitude dust was not over the ice sheets, but over unglaciated regions close to the expanded dust source region in central Asia. In the tropics the change in forcing is estimated to be overall negative, and of similarly large magnitude (-2.2 to -3.2 W m^{-2}) to the radiative cooling effect of low atmospheric (CO_2). Thus, the largest long-term climatic effect of the LGM dust is likely to have been a cooling of the tropics. Low tropical sea-surface temperatures, low atmospheric (CO_2) and high atmospheric dust loading may be mutually reinforcing due to multiple positive feedbacks, including the negative radiative forcing effect of dust.

References

Werner, M., Tegen, I., Harrison, S.P., Kohfeld, K.E., Prentice, I.C., Balkanski, Y., Rodhe, H. and Roelandt, C. 2002. Seasonal and inter-annual variability of the mineral dust cycle under present and glacial climate conditions. J. Geophys. Res. 108, 4744, doi:10.1029/2002JD002365

Claquin, T., Roelandt, C., Kohfeld, K.E., Harrison, S.P., Tegen, I., Prentice, I.C., Balkanski, Y., Bergametti, G., Hansson, M., Mahowald, N., Rodhe, H. Schulz, M. 2003. Radiative forcing of climate by ice-age atmospheric dust. Climate Dynamics, 20, 193-202, doi: 10.1007/s00382-002-0269-19

Impact of off-line technique on air-quality model results

Gunilla Svensson

Meteorological fields are required inputs for Air-Quality Models and it is evident from many studies that the errors in these inputs may contribute considerably to uncertainties in the simulations of airborn chemical species. From a scientific point of view, the most logical approach is to solve both the meteorology and chemistry at the same time on the same grid. The difference in computational time is not very large since the chemical species are normally many more than the meteorological forecast variables. This study investigates the influence of the interpolation time on the chemical calculations, from on-line to 6h interpolations. The day chosen for this study is 14 September 1994 and the location is the city of Athens in Greece Observations for this area is available from the experimental part of the project MEDCAPHOT–TRACE (Mediterranean Campaign of Photochemical Tracers – Transport and Chemical Evolution). Statistical measures are calculated for all simulations and no significant difference is found for these measures for the wind field. However, the simulated ozone concentrations changes when interpolated meteorological fields are used instead of the on-line simulation. Further analysis shows that for example the area that exceeds the critical level 110 µg m^{-3} increases with 65% when interpolation using data every hour instead of on-line simulation. In addition, the number of hour increases from 4 to 6 for exceeding the warning alert threshold. For this case, the amount of chemical and meteorological stations is not enough to make it possible to distinguish which simulation that is closest to the truth. However, this study shows that interpolation, only in time, gives quite a large impact on the chemical results.

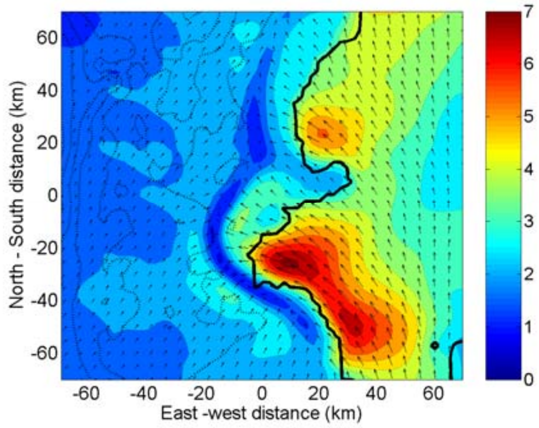
New England Air-Quality Study

Michael Tjernström, Mark Žagar and Wayne Angevine (NOAA/AL, USA)

The New England Air Quality Study (NEAQS 2002, http://www.al.noaa.gov/neaqs) was conducted in July and August 2002. The motivation was the frequently exceeded regulatory standards for ozone along the coast of New Hampshire and Maine, in spite of quite limited local emissions. These are instead located farther south, e.g. along the Boston/New York metropolitan corridor, and pollutants are often transported to the New Hampshire and Maine coastlines across colder ocean water; a pool of cold water typically persist offshore in the northern and eastern Gulf of Maine and the Bay of Fundy. As a result, high-pollution episodes are often not related to stagnation periods as in some other highly polluted coastal areas, for example Los Angeles in California or Athens in Greece, but are instead related to mesoscale coastal circulations such as sea breezes.

In this study we utilize the COAMPS™ mesoscale model to investigate the transport of inert tracers released from Boston and New York, respectively, for two cases, one with weak and one with strong synoptic scale forcing. An unexpected feature in the simulations for both cases is a very strong diurnal offshore flow, presumably an inertial oscillation triggered by the breakdown of the mesoscale pressure gradient due to the daytime land-sea temperature contrast. Another peculiar feature is the return flow in the sea breeze, which has the appearance of a gravity wave triggered by the sea breeze front, more than a classical return flow.

The sea breeze has a significant impact on the simulated tracer concentrations. Much of the low-level tracer that during the night is advected off shore is during the day caught up by the sea breeze circulation and advected inland with high local concentrations as a consequence. On the other hand, the stronger wind case also showed some coastal influence. While most of the tracer advected off shore remained over the ocean, it still remained close to the slightly curving coast and affected other locations very far downstream although at rather low concentrations.



Wind speed and vectors for the August 13 case, with two partly separate sea breeze systems and a clear sea-breeze front.

Scale dependence of air pollution modelling (marine effects of atmospheric deposition, MEAD)

Michael Tjernström, Gunilla Svensson and Mark Žagar

Advanced regional air-pollution models often have limited horizontal resolution, since they often have to cover a sizeable domain and with advanced atmospheric chemistry the computational burden is often high. Some models even use a 1-D Lagrangian framework, driven off-line by weather forecast model output to minimize the computation cost.

In this study we utilize the COAMPS™ mesoscale model to investigate the sensitivity of the surface deposition of an inert tracer on the model horizontal resolution. To do this, we ran the model both for a real case from Kattegat between Sweden and Denmark, and for hypothetical cases with a straight coast. The same conditions are modeled repeatedly with increasing horizontal resolution and the resulting deposition is up-scaled to the same coarse resolution. Details in the deposition differ substantially at different resolution, and local deposition integrated over several hours may be different by an order of magnitude or more depending on resolution. Also, the area-integrated deposition is significantly different. The idealized straight coastline simulations show that the scale of the simulated dynamical phenomena determines the optimal model resolution and not the deposition-model details, and that for example for sea-breeze simulations this may require a resolution of 5 km or better. This is due to the fact that with higher resolution, the atmospheric dynamics becomes more fine-scaled, and tracer is advected differently in space and at higher concentrations compared to in a coarse resolution model.

References

Žagar, M., G. Svensson and M. Tjernström. 2003. A method for determining the small-scale variability of the surface turbulent momentum flux seaward of the coast. Journal of Applied Meteorology, 42, 291-307

Žagar, M., G. Svensson and M. Tjernström. 2005. High spatial and temporal variability of dry deposition in a coastal region, Environmental Fluid Mechanics, Accepted

The spatial variability of atmospheric DMS – a model approach

Jenny Mattsson, Caroline Leck and Gunilla Svensson

See Arctic Studies

ADDITIONAL PUBLICATIONS: CHEMICAL METEOROLOGY

Leck, C., J. Heintzenberg, and M. Engardt. 2002. A meridional profile of the chemical composition of submicrometer particles over the Atlantic Ocean: aerosol sources and hemispheric variabilities, Tellus 54B(4), 377-384

Leck, C., M. Tjernström, P. Matrai and E. Swietlicki. 2004. Microbes, clouds and climate: Can marine microorganisms influence the melting of the Arctic pack ice? EOS Transactions, 85, 25-36

Leck, C., M. Tjernström, P. Matrai, E. Swietlicki and E.K. Bigg. 2004. Can Marine Micro-organisms Influence Melting of the Arctic Pack Ice?, Eos Vol. 85, No 3, 25-36

Nilsson, E.D., and C. Leck. 2002. A pseudo-Lagrangian study of the arctic remote marine sulfur cycle. Tellus 54B, 213-230

Sigg, R., and G. Svensson. 2004. Three-dimensional simulation of the ASTEX Lagrangian 1 field experiment with a regional numerical weather prediction model. Quarterly Journal of the Meteorological Society, 130, 707-724

Steffen, W., Andreae, M., Bolin, B., Cox, P., Crutzen, P., Cubasch, U., Held, H., Nakicenovic, N., Scholes, R., Talaue-MacManus, L., and Turner, B. 2004. Abrupt Changes, The Achilles' Heels of the Earth System. Environment, 46, No 3, 6-20

Svensson, G., and J.H. Seinfeld. 2002. A numerical model of the cloud-topped marine boundary layer with explicit treatment of supersaturation-number concentration correlations. Quarterly Journal of the Meteorological Society, 128, 535–558

Wuebbles, D.J., Brasseur, G.P. and Rodhe, H. 2003. Changes in the chemical composition of the atmosphere. In Brasseur, G.P., Prinn, R.G. and Pszenny, A.P. (eds.) Atmospheric Chemistry in a Changing World. Springer Verlag Berlin. 1-17

ATMOSPHERIC PHYSICS

The research programme in atmospheric physics concentrates on the physics and chemistry of gases, aerosol particles and clouds in the atmosphere. The aeronomy of the middle and upper atmosphere, from an altitude of roughly 10 km to the edge of space, remains a central part of AP's research. However, the changes in AP personnel during the period 2003/4 have seen the research focus expand, at least for a while, to also include tropospheric aerosol studies.

The Atmospheric Physics division has continued to undergo serious changes during the years 2003-2004. Kevin Noone was appointed in 2001 the group's leader and his aerosol group merged into AP, while Jacek Stegman remained co-ordinator of the group's space activities. Prof. Noone's own main scientific interests are in the subject of aerosol-cloud-climate interactions. His activities also included measurements with airborne instruments. Douglas Nilsson joined the group at the end of 2002, bringing two post-doctoral researchers and two graduate students with him. His areas of research include determining the sources of aerosol particles in the lower atmosphere. A period of consolidation and integration of the two programmes followed. However, in September 2004 Kevin Noone left MISU/IMI to take up a position with the Royal Swedish Academy of Sciences as an executive director of the International Geosphere-Biosphere Programme. By the end of 2004 Douglas Nilsson also left IMI/MISU to join the Institute of Applied Environmental Research (ITM).

In September 2002 Jörg Gumbel returned to the group from a postdoctoral stay at the Naval Research Laboratory (NRL), Washington D.C. and NASA's Goddard Space Flight Center, Maryland, USA, strengthening the group's research efforts in the middle and upper atmosphere. During the 2003/4 period four new Ph.D. students have been appointed with the group, all planing to focus their activities on aeronomy of the middle atmosphere. At the beginning of 2005 we are actively working on issues ranging from interpretation of satellite-borne spectroscopic measurements of the entire atmosphere (from tropospheric aerosols to metallic layers in the mesopause region), through modelling the links between the dynamics and chemistry of the stratosphere and mesosphere, to in situ probing the mesosphere with rocket-borne instrumentation.

SATELLITE STUDIES

The Swedish Odin satellite was launched on 20 February 2001 after more than 10 years of design and preparatory work. Odin-related studies take now up a major part in the activities of the section for atmospheric physics. We are involved in both instruments on the satellite, i.e. the Optical Spectrograph and Infrared Imaging System (OSIRIS) and the Sub-Millimetre Receiver (SMR). During the recent two years, our studies have involved both the mesospheric and stratospheric mission of Odin.

Development of retrieval techniques for determination of aerosol optical thickness (AOT) over ocean surfaces from top-of-atmosphere (TOA) radiance using nadir looking instruments of the ocean colour type like Sea viewing Wide Field Sensor (SeaWiFS) and MERIS is another on-going project.

The AP group has also been involved in the recently completed Phase A1 study for a new atmospheric satellite mission designated STEAM (Stratosphere-Troposphere Exchange And climate Monitor). The STEAM satellite project is dedicated to the investigation of chemical, dynamical, and radiative processes in the upper troposphere and lower stratosphere (UT/LS) and their links with the Earth climate and stratosphere evolution.

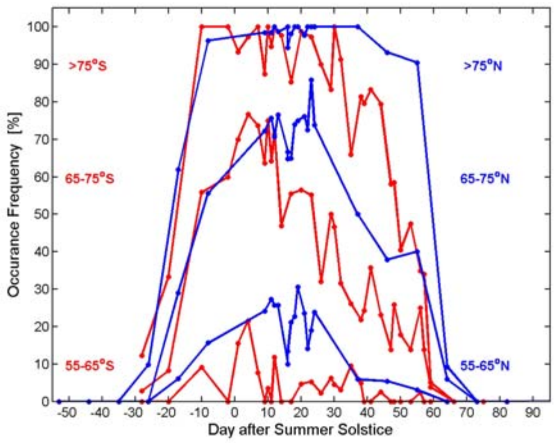
Studies of noctilucent clouds

Bodil Karlsson, Jörg Gumbel, Jacek Stegman, Georg Witt

Noctilucent clouds (NLC) at about 82 km and their mesospheric environment continue to play a central role in MISU's atmospheric physics research. During the summer months, NLCs are observed as a virtually complete cloud cover at latitudes above 70^o and with sporadic occurrence at latitudes down to 50^o. The OSIRIS optical spectrometer onboard the Odin satellite provides unique opportunities to study NLCs over the entire spectral range 275-815 nm. Spectral features allow us to draw conclusions about cloud particle properties. Retrieval algorithms are under development.

Additionally, Odin observations supply continuous information about the seasonal and geographical NLC climatology. Examples from two NLC seasons are given in the figure below. Transitions periods, i.e. the beginning of the NLC season in spring and the end in late summer, are of particular interest; their study contributes to a broader understanding of the atmospheric circulations at these high altitudes. The summer mesospheric campaign in 2004 was therefore scheduled for the second half of August when the NLCs vanish.

Odin allows us to combine data sets that will provide a more complete picture of the polar mesopause region and noctilucent cloud climatology. Retrievals of water and temperature from the SMR instrument will be compared to the NLC data. A new focus is on the influx and fate of meteoric material in the mesopause region and possible relationships to NLC. This work is closely connected to the MAGIC rocket project and OSIRIS retrievals of mesospheric metal layers.



Occurrence frequency of noctilucent clouds during two summer seasons (blue: Northern Hemisphere 2003, red: Southern Hemisphere 2003/2004). The occurrence frequence is the number of NLC observations divided by the total number of observations. Data are shown for various latitude bands and reveil significant differences towards the end of the NLC season in the two hemispheres.

Studies of the mesospheric sodium layer

Jörg Gumbel, Zeyu Fan, John Plane (University of East Anglia, UK)

In close collaboration with John Plane at the University of East Anglia, U.K., a specific OSIRIS project is devoted to the climatology of mesospheric sodium. The sodium atom belongs to the family of metal atoms of meteoric origin (Na, K, Fe, Mg and Ca) found between 80 and 120 km. These atoms are part of a number of chemical cycles involving both ions and neutral species. Specifically, the sodium bicarbonate molecule, postulated as an end product of these reactions, has been proposed as a potential condensation nucleus for NLC particles. Lidar experiments and our own earlier rocket experiments show that during the summer the sodium concentration is strongly reduced, and below 85 km the atom is completely depleted.

Our study addresses the relation between the free sodium density on one hand and the dynamic and chemical evolution of the mesopause region during the summer season on the other. Obviously, sodium and related compounds are also closely connected to the objectives of the MAGIC project with its focus on metallic condensates in the mesosphere. The following scientific topics are addressed in this study:

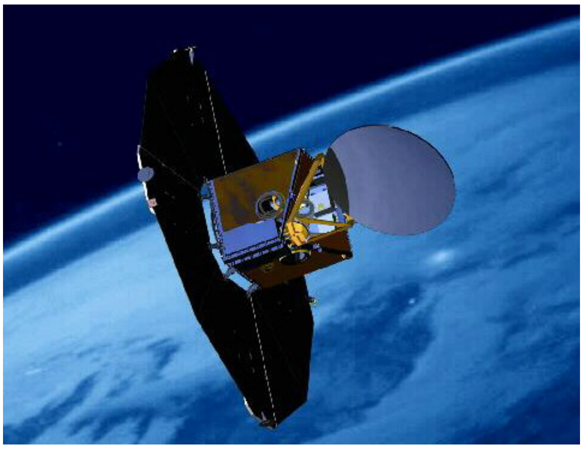
- global climatology of sodium layer
- vertical structure of the layer and its relation to NLC
- chemical modelling of the sodium layer

Remote sensing of the sodium abundance is based on the resonant scattering of sunlight (or a laser beam) at 589 nm. The dayglow intensity of the sodium D-lines is about 2 kR which is seen as a distinct feature in the OSIRIS spectra. Resonance radiative transfor code, a forward model for the sodium dayglow, and optimal estimation retrieval techniques have been developed at MISU. Retrieved vertical profiles of sodium concentrations have been validated against ground-based lidar measurements. An assessment of the global climatology of the sodium layer is now under way. Future plans comprise similar studies for iron and potassium atoms.

The Odin Mission

Jacek Stegman, Jörg Gumbel, Bodil Karlsson, Stefan Lossow, Georg Witt

The AP group remains strongly engaged in the Odin aeronomy programme. A particular focus is on mesospheric water (water vapor, noctilucent clouds) and the continued engagement in the OSIRIS instrument with further development of UV-Vis retrieval algorithms algorithms both for molecular species and aerosols. A new project has been started with the aim to study global cli-mato-logy of the sodium layer in the mesopause region with the help of OSIRIS sodium dayglow measurements.



The Swedish-led Odin satellite was launched on February 20, 2001, as a co-operative effort of Sweden, France, Finland and Canada.

The Odin mission involves close co-operation with a number of scientific groups from the other participating nations – Canada, France and Finland. Odin is the third scientific satellite in a series of Swedish small satellite projects supported by Swedish National Space Board and other national agencies. The main scientific goal of the Odin project is to explore the middle and upper atmosphere and interstellar medium using new, unexplored areas of the electromagnetic spectrum, around wavelengths of 0.5 mm and 3 mm. The instruments used are a submillimetre/millimetre receiver (SMR) and an optical instrument OSIRIS (Optical Spectrometer and InfraRed Imaging System). The latter is used exclusively for atmospheric studies and provides complementary information on the atmosphere using UV, visible and infrared wavelengths. For aeronomy Odin follows the Earth limb, operating alternatively in one of the three limb scanning modes: stratospheric (7-60 km, basic stratospheric mode of operation, every 3 rd day), stratospheric-mesospheric (7-110 km, every 9th day or every 2nd-3rd day during NLC season) and summer mesospheric (65-110 km, on campaign basis), scanning up and down the Earth's limb at a rate of 0.75 km/s

References

Llewellyn, E.J., N.D. Lloyd, D.A. Degenstein, R.L. Gattinger, S.V.Petelina, A.E. Bourassa, J.T. Wiensz, E.V. Ivanov, I.C. McDade, B.H. Solheim, J.C. McConnell, C.S. Haley, C. von Savigny, C.E. Sioris, C.A. McLinden, E. Griffioen, J. Kaminski, W.F.J. Evans, E. Puckrin, K. Strong, V. Wehrle, R.H. Hum, D.J.W. Kendall, J. Matsushita, D.P. Murtagh, S. Brohede, J. Stegman, G. Witt, G. Barnes, W.F. Payne, L. Piché, K. Smith, G. Warshaw, D.-L. Deslauniers, P. Marchand, E.H. Richardson, R.A. King, I. Wevers, W. McCreath, E. Kyrölä, L. Oikarinen, G.W. Leppelmeier, H. Auvinen, G. Mégie, A. Hauchecorne, F. Lefèvre, J. de La Nöe, P. Ricaud, U. Frisk, F. Sjoberg, F. von Schéele, L. Nord. 2004. The OSIRIS Instrument on the Odin Spacecraft, Canadian Journal of Physics, 82, 411-422

Ricaud, P., F. Lefèvre, G. Berthet, D. Murtagh, E. J. Llewellyn, G. Mégie, E. Kyrölä, W. Leppelmeier, H. Auvinen, C. Boonne, S. Brohede, D. A. Degenstein, J. de La Noë, E. Dupuy, L. El Amraoui, P. Eriksson, W. F. J. Evans, U. Frisk, R. L. Gattinger, F. Girod, C. S. Haley, S. Hassinen, A. Hauchecorne, C. Jimenez, E. Kyrö, N. Lautié, E. Le Flochmoën, N. D. Lloyd, J. C. McConnell, I. C. McDade, L. Nordh, M Olberg, A. Pazmino, S. V. Petelina, A. Sandqvist, A. Seppälä, C. E. Sioris, B. H. Solheim, J. Stegman, K. Strong, P. Taalas, J. Urban, C. von Savigny, F. von Scheele, and G.Witt. 2004. Polar vortex evolution during the 2002 Antarctic major warmings observed by the Odin satellite., J. Geophys. Res. (in print)

Sioris, C.E., C.S. Haley, C.A. McLinden, C. von Savigny, I.C. McDade, J.C. McConnell, W.F.J. Evans, N.D. Lloyd, E.L. Llewellyn, K.V. Chance, T.P. Kurosu, D. Murtagh, U. Frisk, K. Pfeilsticker, H. Boesch, F. Weidner, K. Strong, J. Stegman and G. Megie. 2003. Stratospheric profiles of nitrogen dioxide observed by Optical Spectrograph and Infrared Imager System on the Odin satellite., J Geophys. Res., 108, D7, 10.1029/2002JD002672

DOAS studies of stratospheric chemistry

Bodil Karlsson, Jacek Stegman

OSIRIS, the optical spectrograph on Odin provides spectra of the sunlit Earth limb in the UV-Vis spectral region (275-815 nm). For standard processing of O_3 retrievals, a 3-wavelength method has been established in the Chappuis wavelength region. However, vertical column densities of ozone and a number of minor species relevant for stratospheric ozone chemistry (NO_2, OClO and BrO) can also be retrieved by a combination of modelling and the DOAS technique (Differential Optical Absorption Spectroscopy). This retrieval method and its sensitivity to various instrumental effects have been extensively studied during the years before the Odin launch. A comparison of this DOAS technique in the Huggins bands region and the standard 3-wavelength method was a subject of a last year project completed in 2003.

In this project, the DOAS technique was applied to limb observations from the Odin satellite in the 345-390 nm wavelength range to retrieve slant column densities of O_3, NO_2, OClO and BrO. The retrieved global distribution of the four species was successful in reproducing chlorine activation and denitrification processes in the northern hemisphere in the region of the northern polar vortex. Thus, the DOAS technique was proven to provide realistic and important information. A validation of the ozone slant column densities was performed by comparing the results with ozone densities deduced with the 3-wavelength method. This validation study revealed systematic underestimations when using the DOAS method.

The STEAM satellite mission

Jörg Gumbel, Jacek Stegman

The Stratosphere-Troposphere Exchange And climate Monitor (STEAM) satellite project is dedicated to the investigation of chemical, dynamical, and radiative processes in the upper troposphere and lower stratosphere (UT/LS) and their links with the Earth climate and stratosphere evolution. The main objective is to provide vertically and horizontally resolved information on the global distributions of UT/LS key species such as water vapour, ozone, and carbon monoxide, and global fields of ozone, water and halogen compounds responsible for the ozone distraction in the stratosphere.

STEAM has a strong heritage from the Odin satellite. It carries a many-channel microwave limb-viewing instrument, operating in the 320-360 GHz range to sound the UT/LS and in the 485-505 GHz range to sound the stratosphere. A co-aligned optical instrument will support microwave measurements with cloud indications. In addition, the optical instrument will provide measurements of aerosol and cloud properties, ozone and water vapour.

STEAM has been recommended by SNSB as the next Swedish satellite project but has no funding yet. It is under discussion to combine STEAM with the proposed Canadian satellite project SWIFT that focusses on a global mapping of stratospheric winds. The AP group has been actively participating in the recently completed STEAM phase A1 study. The group's main interest is, at this point, the definition of the optical instrument on STEAM for cloud and aerosol detection and characterisation.

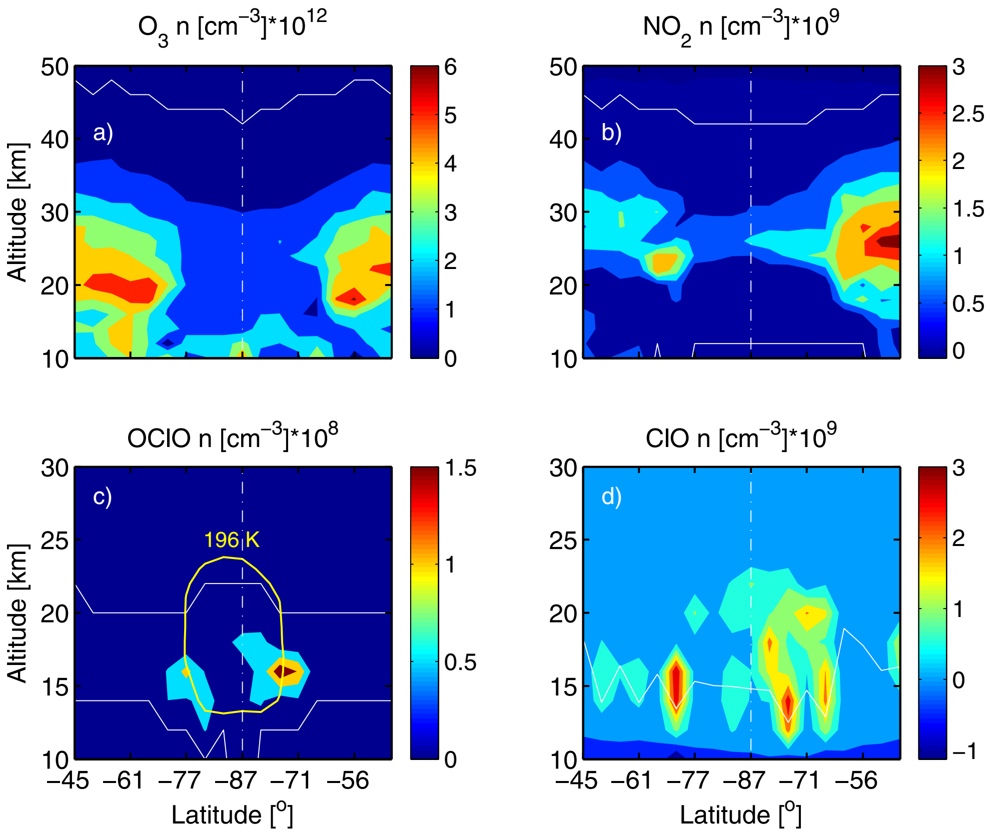
Retrieval of stratospheric OClOvertical profiles

Patricia Krecl, Jacek Stegman

The first vertical profiles of stratospheric OClO have been retrieved from Odin/OSIRIS limb-scattered sunlight radiances in the 403-427 nm spectral region. This work has been carried out in close collaboration with Craig S. Haley (York University, Toronto, Canada), Samuel M. Brohede (Chalmers University of Technology, Göteborg, Sweden), and Gwenaël Berthet (Institut Pierre-Simon Laplace, Paris, France).

Our retrieval method is based on a two-step approach, using differential optical absorption spectroscopy (DOAS) combined with the maximum a posteriori (MAP) estimator. The results show that OClO can be detected inside the southern polar vortex region between about 12 and 20 km altitude with a 2-5 km height resolution and an estimated retrieval noise better than 60% at the peak. OClO concentrations are consistent with chemical transport model simulations and with independent ClO measurements. They show the expected relation to the atmospheric conditions in the lower stratosphere in the austral spring 2002. This unique data set of OClO profiles is very promising to study the stratospheric chlorine activation in both Polar Regions.

The figure displays the number density profiles of O_3, NO_2, OClO, and ClO along the Odin orbit 8565 for latitudes south of 40^oS. All of these measurements were performed at twilight conditions with solar zenith angles ranging from 91.0° to 92.1°. O_3 and NO_2 profiles were derived from OSIRIS measurements while the ClO profiles were retrieved from Odin/SMR spectra. The white lines in the plots indicate the lowermost and uppermost altitudes of significant measurements. Severe ozone depletion is mainly detected between 16 and 30 km, associated with an important denitrification and denoxification of the lower stratosphere as shown by plots a) and b). This is consistent with an OClO enhancement observed in the 10-22 km altitude range where a cold temperature core is also found with temperatures lower than the PSC threshold formation (i.e, < 196 K). An area with large ClO concentrations is observed for altitudes below 20 km (panel d), adhering well with the OClO abundances. The sunrise OClO concentrations are lower than the sunset abundances as depicted in panel c) since the diurnal variation is largely driven by the diurnal cycle of its photolysis rate.



Retrieved number density profiles of a) O_3, b) NO_2, c) OClO, and d) ClO along the Odin orbit 8565 for latitudes southward of 40°S. The white lines in each plot represent the lowermost and uppermost altitude of significant measurements. The yellow line in plot c) represents the isotherm of 196 K. The dashed-dotted line in each plot separates the sunrise (left) and sunset (right) measurements.

Water vapour and temperature retrievals from the Odin sub-mm radiometer

Stefan Lossow, Jörg Gumbel, Jacek Stegman

The submillimeter radiometer (SMR) onboard the Odin satellite measures many minor constituents globally in the middle atmosphere using the frequency range between 486 and 581 GHz. Among the three water vapour lines measured in this frequency range the line at 556.936 GHz is of major interest for the mesosphere. Using a non-linear scheme based on the optimal estimation method (OEM), abundance informations up to 100 km can be derived with an altitude resolution between 3 and 4 km. Up to now just a small fraction of the measurements have been processed and also the optimisation of the non-linear scheme is further ongoing. This work is carried out in close collaboration with Nicolas Lautié and Donal Murtagh at Chalmers Technical University.

Apart from the global distribution of water vapour the scientific focus is mainly on the polar mesopause region, which exhibits layered phenomena during the summer season, like noctilucent clouds (NLC). In order to clarify the relationship between the water vapour distribution and the existence of ice particles forming the NLC, the Odin-SMR water measurements has to be merged together with measurements of OSIRIS (Optical Spectrograph and Infrared Imaging System) onboard Odin, which provides informations about the scattering of UV and visible light. Every 9th day and, in addition, during two weeks of an annual summer mesosphere mission, Odin is therefore performing only measurements in aeronomy mode scanning up to 110 km, to provide extensive coverage with high temporal resolution.

In January 2005, the Odin water vapour measurements will once again be complemented and validated by Hygrosonde rocket and balloon measurements during the MAGIC campaign from Esrange, Sweden.

The ACE satellite mission

Georg Witt, Bodil Karlsson

The ACE experiment onboard the Canadian SciSat satellite performs solar occultation measurements in a polar orbit since 2003. The experiment is dedicated to the study of chemical processes up to the upper stratosphere including the key species involved in the chemistry of Ozone. ACE comprises two optical experiments. The first of these is MAESTRO, a dual-channel grating spectrograph for the near-UV to near-IR spectral range. The second instrument is a BOMEM Fourier spectrometer (FTS) for the wavelength region between 2 and 13 microns. The FTS spectrum offers an extremely high spectral resolution needed to separate weaker spectral features from the strong background of mainly CO_2 and water vapour.

As part of the FTS experiment, the non-structured baseline of the IR spectrum is used to obtain information about the size, shape and composition of stratospheric aerosol particles (J. Sloan, Waterloo University, Waterloo, Ont., Canada). Although the study of mesospheric particles has not been foreseen, the extinction measurements offer an excellent opportunity of complementing the Odin NLC observations, notably during the Odin Summer Mesosphere Mission. Georg Witt has been accepted as adjoint to the ACE Science Team with access to the FTS data. For the noctilucent cloud study the analysis will be done in close cooperation with J. Sloan's group using the data base collected there. The 3.1 μm extinction profiles retrieved during the NLC season from mesospheric heights (up to 100 km tangent altitude) will be examined to establish the absorption of the ice crystals. As to the gas measurements, the water vapour experiment provides useful data up to above the mesopause, thus presenting a highly desirable complement to the ODIN/SMR observations.

Satellite remote sensing of aerosol over ocean surfaces

Paul Glantz

There is a great challenge in adequately characterizing the nature and occurrence of atmospheric aerosols and in including their effects in models to reduce uncertainties in climate prediction. An integrated strategy for reducing uncertainties should include high quality measurements of aerosols from space.

In collaboration with W. von Hoyningen-Huene (IUP, University of Bremen), we have developed a retrieval technique allowing determination of aerosol optical thickness (AOT). This work is based on a retrieval method for the determination of aerosol optical thickness (AOT) over ocean surfaces from top-of-atmosphere (TOA) radiance using nadir looking instruments of the ocean color type like Sea viewing Wide Field Sensor (SeaWiFS). Here the retrieval approach is used for SeaWifs and MERIS data sets over ocean surfaces. Both instruments measures the upwelling or TOA radiance L (λ) and the solar extraterrestrial irradiance E_0 (λ) in the visible and near infrared wavelengths. The retrieval of AOT is based on lookup tables describing relationship between the measured L (λ) and the aerosol optical thickness δ_A (λ). An adequate set of lookup tables is required that takes into account all factors which influence the radiative transfer in the atmosphere: i.e. solar elevation, illumination and observation geometry, Rayleigh scattering, surface reflectance (different vegetation cover over land), the surface elevation with its surface pressure conditions (land), and finally the aerosol parameters (aerosol phase function, aerosol optical thickness etc.).

Results show that enhanced AOT associated with continental anthropogenic aerosols, dust particles, and probably also sea-salt particles as well as aerosols emitted from aircrafts and ships highly influenced the maritime air masses. Retrieval of AOT combined with meteorological data from ECMWF and back trajectories from NOAA help to identify different aerosol types. Finally, a relationship was found between AOT (0.670 nm) and wind speed (ECMWF). The importance of sea-salt particles and/or relative humidity on the increase in reflection is under investigation.

References

Glantz, P., Noone, K. J and Osborne, S. R. 2003. Comparisons of Airborne CVI and FSSP Measurements of Cloud Droplet Number Concentrations in Marine Stratocumulus Clouds., J. Atmos. Ocean. Tech., 20, 133-142

Glantz, P., Noone, K. J. and Osborne, S. R. 2003. Scavenging efficiencies of aerosol particles in marine stratocumulus and cumulus clouds., Quart. J. Roy. Meteorol. Soc., 129, 1329-1350

Glantz, P., Svensson, G., Noone, K. J. and Osborne, S. R. 2004. Sea-salt aerosols over the Northeast Atlantic: Model simulations of ACE-2 2nd Lagrangian experiment., Quart. J. Roy. Meteorol. Soc., 130, 2191-2215

IN SITU STUDIES OF THE MIDDLE ATMOSPHERE

The abundance and transport of chemically active species in the middle atmosphere is a central research topic for the MISU/IMI Atmospheric Physics group. Many important processes in this region are controlled by the interaction of radiation, chemistry as well as local and large-scale dynamics. Prominent examples are phenomena like noctilucent clouds, the Earth's nightglow or the distribution of water vapour. In situ measurements are essential tools for the analysis of these complex interactions governing the middle atmosphere.

Water vapour measurements

Misha Khaplanov, Jonas Hedin, Jörg Gumbel, Jacek Stegman, Georg Witt

The Atmospheric Physics group continuous to develop and apply instruments for the measurement of water vapour in the stratosphere and mesosphere. Presently, this very sensitive technique utilises the photolysis of water molecules by ultraviolet light and the subsequent fluorescence emission from hydroxyl radicals mainly in the 0-0 vibrational band around 310 nm. An on-going project aims now the development of a new, "solar-blind" hygrometers that would permit to extend our in situ water measurements to sunlit conditions. In the lower stratosphere (balloon instruments), this can be achieved by utilizing hydroxyl fluorescence emissions in the 1-0 vibrational band near 290 nm. As the stratospheric ozone layer strongly absorbs at these wavelengths, solar background illumination is efficiently removed. As for daytime measurements in the mesosphere (rocket instruments), dissociation of water at extreme ultraviolet wavelengths leads to fluorescence emissions at even shorter wavelength (H Lyman-α at 121.6 nm) where the solar background is negligible below 70-85 km. Laboratory studies have been started to develop a suitable light source for the extreme ultraviolet region.

As for stratospheric applications, we have developed different versions of compact fluorescence hygrometers. These instruments are fully self-contained with power supply and data acquisition. This design allows flexible and easy use in balloon campaigns. Both the stratospheric and mesospheric hygrometer developments are closely connected to the water vapour measurements by the Odin satellite, to the MAGIC rocket campaign and to our modelling studies in the middle atmosphere.

The Hygrosonde-2 campaign

Misha Khaplanov, Jacek Stegman, Jörg Gumbel, Georg Witt

A complete measurement of the water vapour distribution from the tropopause to the mesopause has been obtained from simultaneous in-situ rocket and balloon measurements conducted from Esrange on December 16, 2001. Hygrometer instruments based on MISU's hydroxyl fluorescence technique were flown both on the Hygrosonde-2 rocket payload and on the SKERRIES balloon. During the same salvo, meteorological rockets provided by NASA measured temperature, density and wind profiles in the upper stratosphere and mesosphere. Additional information on the density profile is available from the Rayleigh lidar at Esrange operated by Bonn University. These detailed local data sets were complemented by an overflight of the Odin satellite, configured in aeronomy mode and providing continuous water measurements using sub-mm limb sounding.

The Hygrosonde-2 measurements were performed close to the edge of the polar vortex in dynamically disturbed conditions prior to a stratospheric warming. Local vertical profiles of temperature and wind reveiled the structure of a persistent mountain wave in the wake of the Scandinavian mountains. The measured distribution of water vapour reflected this dynamical situation, thus confirming the role of water vapour as a tracer for middle atmospheric transport processes. A sharp layer of low humidity between 60 and 70 km was consistent with transport of dry polar vortex air from a region located to the *south* of Esrange over Central Europe. Both Hygrosonde-2 and the earlier Hygrosonde-1 campaign in 1994 suggest an extension of the polar vortex well into the mesosphere. In both cases, horizontal humidity gradients in the vicinity of the vortex boundary were found to be significantly larger than suggested by 2D model studies.

References

Khaplanov, M, J. Gumbel, J. Stegman, G. Witt, P. Dalin, S. Kirkwood, F. J. Schmidlin, K. H. Fricke, U. Blum, N. Lautie, and the Odin Team. 2003. Middle Atmospheric Water Vapour And Dynamics During The Hygrosonde-2 Campaign, Proceedings of the 16th ESA Symposium on European Rocket and Balloon Programmes and Related Research, St. Gallen, Switzerland, 2 -5 June 2003, ESA SP-530, pp.551-556

Robertson, S., B. Smiley, M. Horanyi, Z. Sternovsky, J. Gumbel and J. Stegman. 2004. Rocket-borne probes for charged ionospheric aerosol particles, IEEE Trans. Plasma Science 32(2), pp. 716-723

Mesospheric aerosol – genesis, interaction and composition (MAGIC)

Jörg Gumbel, Misha Khaplanov, Jacek Stegman, Jonas Hedin, Bodil Karlsson, Stefan Lossow, Linda Megner

Intensive work has been going on in the MISU's Atmospheric Physics group to prepare the MAGIC rocket project scheduled for January 2005. The MAGIC project is a close collaboration with the Naval Research Laboratory (NRL) in Washington D.C. and focusses on the fate of meteoric material in the mesosphere.

Approximately 100 ton of sub-mm meteoric particles enter the Earth's upper atmosphere each day. Our knowledge about the fate of this cosmic material is so far very limited. It has been suggested that the material condenses into nanometer-size "smoke" particles, although this concept has never been proven experimentally. Nonetheless, meteoric smoke has been suggested to play key roles in a number of mesospheric processes related to noctilucent clouds, polar mesosphere summer echoes, charge balance, and neutral chemistry. MAGIC aims to sample and to analyse meteoric particles and to relate their distribution to the atmospheric circulation. Detailed in situ measurements of water vapour, density, temperature and winds will determine the dynamical features of interest.

In order to study smoke particles in the mesosphere, a number of related processes willl be addressed by co-ordinated experiments: smoke particle distribution, atmospheric dynamics, charge distribution and neutral tracers. This is the objective of the MAGIC project. Basic scientific questions are:

- Do re-condensed smoke particles of cosmic origin exist in the mesosphere?
- What is the number density and spatial distribution of the particles?
- What is the size distribution of the particles?
- What is their charge state?
- What is the elemental and molecular composition of the particles?

Meteoric smoke particles will be directly sampled in the mesosphere by the MAGIC detectors newly developed at NRL in collaboration with MISU. With this completely new approach, we aim to take mesospheric material down to the laboratory. The particle samples will then be analysed in terms of altitude-dependent number density, size distribution and element composition. These studies involve transmission electron microscopy techniques, x-ray spectroscopy, and isotope determination. The charge state of the particles will be probed in situ by particle impact probes provided by the University of Colorado. In order to study dynamic influences, we will relate the particle distribution to detailed measurements of water vapour as tracer for mesospheric transport. This is done using MISU's optical hygrometer technique. Additional information on the dynamic state of the atmosphere and on ionospheric conditions will be available from met-rockets and the ground-based measurements. Complementary model studies are being prepared in collaboration with NRL and the University of Esat Anglia, U.K.

The instrument package for the MAGIC rocket flight consisting of MISU's hygrometer (center) and three NRL MAGIC particle samplers. The MAGIC campaign is scheduled at Esrange, Sweden, in January 2005.

Lyman-α radiative transfer in the mesosphere

Jörg Gumbel, Georg Witt, Jonas Hedin, Misha Khaplanov

The enhanced Alomar Research Infrastructure (eARI) is a system of high quality ground-based experimental facilities concentrated at the ALOMAR observatory and the Andøya Rocket Range in Norway. Recently, the new EU contract to eARI has been extended to the sponsoring of two sounding rocket launches from Andøya (see http://alomar.rocketrange.no). The rockets will be divided into one launch in noctilucent cloud conditions, the other for ionospheric experiments at higher altitudes. Costs of launch, integration and transports are fully covered by the EU contract.

The MISU Atmospheric Physics group is preparing an eARI experiment that will study the hydrogen Lyman-α radiation field in the sunlit summer mesopause environment. The Lyman-α line is the only far-UV feature capable of penetration through the massive absorption by molecular oxygen to below the mesopause. Because of its 9.5 eV energy, the hydrogen emission is capable of ionising nitric oxide (the source of the ionospheric D-layer and starting step in the complicated ion chemistry of the cold mesopause region) and, not the least, of dissociating H_2O (the final decomposition of mesospheric water vapour). Since one has to do with resonance radiation, the Lyman-α line is diffusively scattered by the hydrogen atoms of the geocorona, a light source comparable at low altitudes to direct sunlight.

The presence of a light-scattering aerosol is expected to modify the radiative transfer of the hydrogen line. We will therefore also measure the light scattering at 121.6 nm by noctilucent cloud particles. This measurement will constitute a highly desirable complement to the scattering observations from Odin. Notably, it will provide constraints on the particle size distribution that normally needs to be assumed when inverting multi-wavelength NLC spectra.

GROUND BASED STUDIES

Oxygen airglow

Jacek Stegman

The systematic study of temporal variability of the oxygen-related nightglow has now been interrupted since the Institute's optical site Sandkullen in the Northern Stockholm suburban region had to be closed down. The collected time series extends over an entire solar cycle. The measurements were made automatically on every clear night utilising a highly luminous 1-m Ebert-Fastie spectrometer and a battery of complementary filter photometers.

The analysis of these data led to the discovery of springtime depletion of atomic oxygen in high latitude mesopause region more recently also labelled "a springtime transition". The transition appears to be a global phenomenon, associated with a planetary scale redistribution of atomic oxygen due to the reversal of the large-scale circulation patterns. The analysis work proceeds.

References

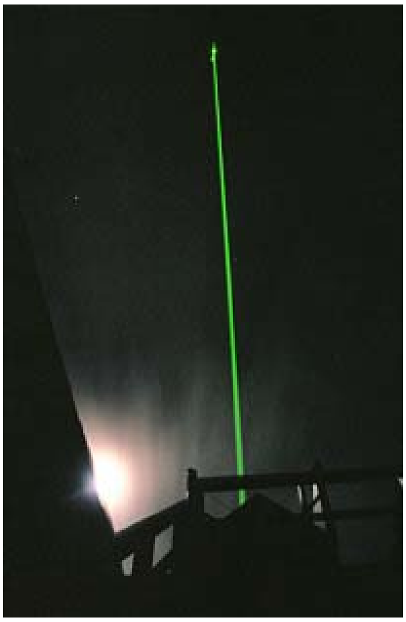
Beig, G., P. Keckhut, R. P. Lowe, R.G. Roble, M. G. Mlynczak, J. Scheer, V. I. Fomichev, D. Offermann, W.J.R. French, M. G. Shepherd, A. I. Semenov, E. E. Remsberg, C. Y. She, F. J. Lübken, J. Bremer, B. R.Clemesha, J. Stegman, F. Sigernes, and S. Fadnavis. 2003. Review Of Mesospheric Temperature Trends., Review of Geophysics, 41, 4, 1015, 10.1029/2002RG000121, WMO Norbert Gerbier-MUMM International Award 2005

Lidar measurements in the middle atmosphere

Jonas Hedin, Bodil Karlsson, Stefan Lossow, Linda Megner, Jörg Gumbel

Since summer 2004 the MISU Atmospheric Physics group is involved in lidar measurements carried out with the lidar of the Bonn University at Esrange. This activity is at the moment a complement to rocket campaigns conducted at Esrange, such as the MAGIC campaign in January 2005. The Bonn lidar is a Rayleigh/Mie/Raman (RMR) lidar transmitting light of wavelenghts 532 and 1064 nm into the atmosphere, where it is scattered by atoms, molecules and aerosols. The light which is backscattered at 180° is collected by three bore sighted Newtonian telescopes, each with a diameter of 50.8 cm, and then detected by several different channels. From the backscattered signal it is possible to derive temperature and density profiles, to detect clouds and aerosol layers and to estimate some properties of the aerosol particles. This information can be obtained between 5 and 100 km, depending on the geophysical conditions.

During the MAGIC rocket campaign simultaneous measurements with additional lidars are planned; the stratospheric lidar located at IRF and the ALOMAR RMR lidar located on the Northern Norwegian island of Andøya, west of the Scandinavian mountain ridge. This offers a unique possibility to study the dynamics of gravity waves on both sides of a major source of orographically induced waves.



The laser beam of the Bonn Univerity lidar at Esrange.

Bi-static lidar studies of cirrus particle properties

Georg Witt

Under the 6th Frame Programme of the European Union, the EU is promoting and financing the utilisation the ALOMAR Research Infrastructure (ARI) at Andøya, Norway. A co-operative project that currently enjoys EU's support is the experiment CABLE (Co-operative Alomar Bi-static Lidar Experiment) which makes use of the laser beam emitted by one of the powerful ALOMAR laser transmitters to study the scattering properties of tropospheric ice clouds and aerosol particles. The main objective of the study is to assess the shape and possible orientation of the scattering particles, parameters not readily accessible by the common lidar backscatter observing mode. In contrast to the conventional lidar backscatter technique, the bi-static experiment records the scattered radiation of the vertically propagating laser beam from a remote site a few kilometres from the lidar transmitter. The rationale of this set-up is that the measurement can be extended to scattering angles of 130-170º where the polarisation parameters of the scattered light are sensitive indicators of the effect of non-sphericity of the scattering centres.

CABLE is a co-operation between the Hebrew University of Jerusalem (A. Cohen and G. Witt as visiting scientist) and the Atmospheric Science Group at the Chemistry Department of Göteborg University. (Jan Pettersson, with G Witt as informal thesis adviser). The instrumentation used for the study is a polarisation-sensitive lidar receiver, an updated version of the MISU lidar system used in the years 1965-71.

AEROSOLS AND RADIATION

This research has taken an integrated approach to learning about the atmosphere by combining in situ measurements of aerosols, clouds and trace species, remote sensing studies of these quantities, and process-scale model investigations. A process-based approach has been adopted to the determination of how anthropogenic emissions of aerosols and gases influence cloud properties (both microphysical and chemical), and how aerosols and clouds affect the radiative balance of the Earth. Process information is then combined with satellite measurements to determine the nature and extent of the anthropogenic modification of the natural background aerosol and cloud fields, and detailed microphysical-chemical models are linked with field observations to explore and understand the processes behind trace gas-aerosol-cloud-climate interactions.

European Fleet for Airborne Research – EUFAR

Radovan Krejci, Kevin Noone and 23 international partners, Co-ordinator J.L. Brenguier, Meteo-France, Tolouse, France

EUFAR is an Infrastructure Cooperation Network of the European Commission HPRI programme under FP5/FP6. EUFAR aims at coordinating the operations of the European fleet of instrumented aircraft in the field of environmental research in the atmospheric, marine, terrestrial and Earth sciences.

EUFAR aims at: 1) Co-ordinating the network for exchanging knowledge, sharing developments, and building the unified structure that is required for improving access to the infrastructures. 2) Providing users with Transnational Access (TA) to the infrastructures. 3) Extending TA to national funding sources, 4) Promoting airborne research in the academic community, 5) Developing research activities in airborne instrumentation.

MISU participation is focused mainly on Joint Research Activity (JRA) part of EUFAR. The objective of the EUFAR JRA1 "Airborne Aerosol Reference Pod" is to design and construct an Aerosol Reference Pod that can be flown on several aircraft and will serve as a true basis for intercalibration of airborne aerosol instrumentation.

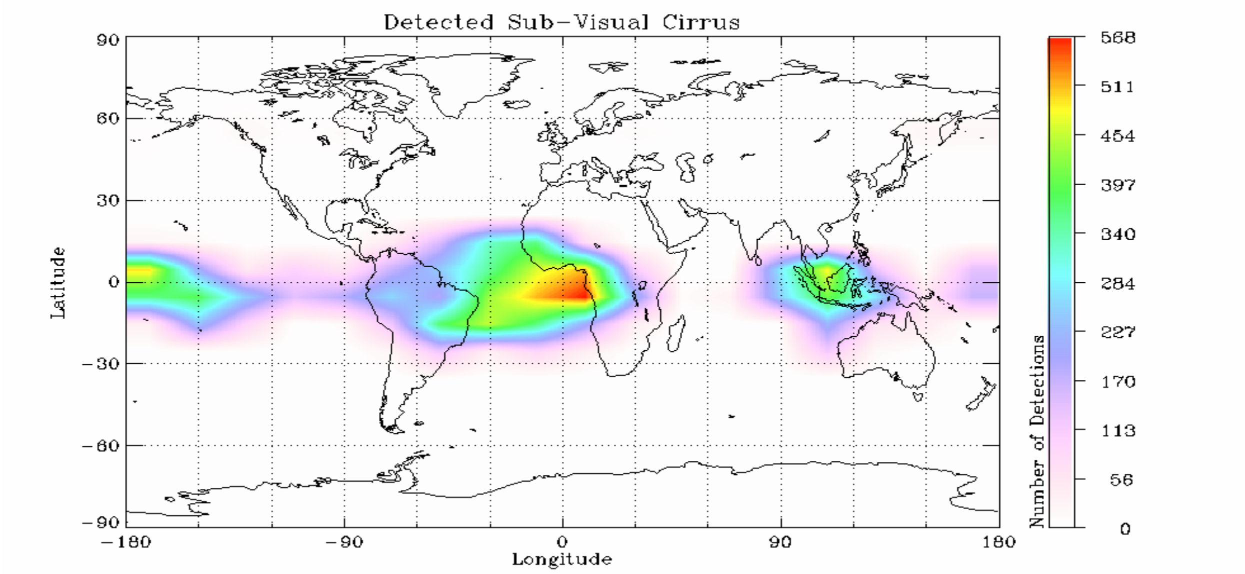
Detail information can be found on project website: www.eufar.net

Sub-visible Cirrus Clouds and Clouds in the Tropopause Region

Kevin Noone, Paul Glantz and Adam Bourassa, Douglas Degenstein and Edward Llewellyn (University of Saskatchewan, Canada)

Cirrus clouds can act to either cool or warm the planet, depending on their optical thickness. Previous investigations (measurement campaigns and model simulations) into cirrus clouds have focused on understanding the mechanisms by which large concentrations of small ice crystals can be produced. These small crystals are important in determining the optical characteristics of cirrus clouds, which in turn determine how the clouds affect radiation transfer through them. Measurements have indicated that sub-micron aerosols control the number population of these small crystals, and that the relationship between residual particle size and cloud droplet size commonly observed in warm clouds does not hold for cirrus clouds. Consequently, understanding what controls the radiative properties of cirrus clouds requires an understanding of what aerosol controls the number population of small crystals.

Optically thin cirrus clouds (sub-visible cirrus) are of particular interest because of their potential influence on the Earth's radiative balance. The few measurements that have been made in these clouds indicate that the crystals are typically small – under 20 µm or even 10 µm or less. Recent research has measured the concentration, condensed water content and nitric acid concentration of crystals in clouds in the tropical tropopause region. Current work is using the Odin and SeaWIFS satellites to investigate the occurrence and properties of sub-visible clouds, including sub-visible cirrus clouds near the tropopause (figure below). An advantage of the limb scanning observational approach used by Odin is that information about the vertical distribution of these clouds is available (at least above about 7-8 km). To date, all of the clouds examined have been at or below the thermal tropopause height. Future investigations will examine whether the spatial distribution of the clouds is determined by purely dynamical driving forces, or whether there is spatial co-variation between cloud fields and aerosol fields.



Occurrence of sub-visible cirrus clouds in the tropics during April, 2002. (Source: A. Bourassa, D. Degenstein, N. Lloyd and E. Llewellyn, University of Saskatchewan).

Aerosol/Cloud Interactions and Organic Cloud Droplet Nuclei

Kevin Noone, Admir Targino, Gustavo Olivares, Lynn Russell (Princeton University), John Ogren (NOAA), David Covert (University of Washington, Seattle) and collaborators at University of Mainz, Germany

Every cloud droplet starts its life as an aerosol particle. Understanding natural clouds, and how anthropogenic pollution affects cloud formation and development, requires understanding the processes that determine what fraction of the available aerosols actually form cloud droplets, and how this fraction is influenced by particle microphysics and chemistry.

To tackle these issues a sampling system was developed that separates cloud droplets from the air and surrounding interstitial aerosol particles, samples and evaporates the droplets, and determines the properties of the aerosols on which the droplets formed (the droplet residual aerosol particles). A major outstanding question after initial investigations was the extent to which particle chemistry, particularly the chemistry of organic compounds, influence cloud droplet formation.

A field experiment conducted in July 2003 at Mt. Åreskutan in central Sweden investigated the efficiency with which particles, particularly those containing organic species, form cloud droplets. A land-based Counterflow Virtual Impactor (CVI) system was used to sample cloud droplets, and a radial impactor was used to sample interstitial aerosol particles. Attached to both systems was instrumentation to determine the concentration, size, optical properties (scattering and absorption coefficients) and chemical composition of the residual and interstitial aerosol. An aerosol mass spectrometer was used to determine the size-resolved chemical composition of the residual and out-of-cloud aerosol.

Preliminary analyses revealed that organic compounds accounted for up to 60% of the aerosol mass, both in clean and polluted air. Particles smaller than 0.2 µm were a surprisingly large fraction of the cloud droplet residuals. During overnight drizzle the residual aerosol distribution mode decreased to well below 0.1 µm, but increased again in the morning when the drizzle stopped. The drizzle appeared to have played an important role in modulating the concentration of accumulation-mode particles during this period.

MODELLING OF ATMOSPHERIC PHYSICS

Modelling efforts in the Atmospheric Physics group have become increasingly important in order to put our measurements into a larger perspective. Significant progress has been made in connection with the Odin mission. Similar efforts are needed for our in situ measurements. New collaborations have been started both on chemistry/transport studies in the middle atmosphere and the radiative transfer related to present and future missions.

Simulations of rocket-borne in situ measurements

Jonas Hedin, Jörg Gumbel

Much effort has been focused on both the developement of new instruments and the developement of appropriate analysis methods. Aerodynamic influences on rocket-borne measurements play an important role in this respect. We use a Direct Simulation Monte Carlo model, the DS2V model by G. A. Bird, for detailed simulations of rarefied gas flows. During the recent two years, our simulations have been applied to the analysis to a number of European and U.S. rocket expriments.

For many in situ probes, interactions with mesospheric particles (ice or smoke), ions and electrons are of particular interest. We have developed a model that traces particles in the airflow about payloads and instruments. This model has been used to study various particle impact measurements, such as the German ECOMA detector that was launched from Esrange in October 2004, and was of central importance also for the design of the MAGIC experiment. We intend to extend this model to include the flow of ions, payload charging and electric fields.We are part of NASA's CAPPS project (Charging of Aerosol Particles in the Polar Summer), with Richard Goldberg as Principal Investigator, that aims at improved analysis techniques for rocket-borne studies of mesospheric phenomena.

Sensitivity of the middle atmosphere to doubling of CO_2: chemical analysis of the ozone radiative feedback

Jonsson, A. I., J. de Grandpré, V. I. Fomichev, J. C. McConnell, and S. R. Beagley (University of Toronto, Canada)

The Canadian Middle Atmosphere Model (CMAM) is a three-dimensional coupled chemistry-climate model (CCM), stretching from the ground to the mesopause. It has a wave driven dynamics, a comprehensive radiation scheme, interactive chemistry, and includes standard tropospheric processes. In collaboration with University of Toronto and York University we have analysed the impact of increases in CO_2 mixing ratios on the middle atmosphere. In particular, the photochemical response and radiative feedbacks through ozone changes on the temperature has been investigated. The results indicate that a doubling of CO_2 cools the upper stratosphere and mesosphere by up 10-12 K and induces up to 20% increases in ozone concentrations. Non-interactive simulations show that the temperature response is overestimated by up to 4.5 K when the ozone radiative feedback is not considered. Detailed analyses of the ozone photochemical steady state reveals the most of the ozone response is governed by the temperature dependence of the odd oxygen partitioning reaction $O+O_2+M \rightarrow O_3+M$. These results have been published and currently the project is being continued by an examination of the impact of changes in sea surface temperatures and sea ice conditions on the upper atmosphere.

References

Jonsson, A. I., J. de Grandpré, V. I. Fomichev, J. C. McConnell, and S. R. Beagley. 2004. Doubled CO2-induced cooling in the middle atmosphere: Photochemical analysis of the ozone radiative feedback, J. Geophys. Res., 109, D24103, doi:10.1029/2004JD005093

1-d and 2-d model simulations of mesospheric aerosols

Linda Megner, Jörg Gumbel

Meteoroid ablation provides a substantital input of metallic species into the lower thermosphere and mesosphere. This meteoric material is believed to re-condensate to nanometer-size so-called "smoke particles", which have been suggested to play an important role in the mesosphere, for instance in the formation of noctilucent clouds. However, very little is known about these particles, their composition and global distribution.

The MISU-1D Model which includes comprehensive gas phase chemistry and radiation schemes as well as vertical transport by advection and by diffusion, is being further developed to include the chemistry related to smoke particles. A coagulation scheme for the smoke particles is being developed as an input for global transport simulations of the particles. Future simulations are planned with the CHEM-2D chemical/transport model of the Naval Research Laboratory in Washington D.C. A major aim is to model the global production and distribution of smoke particles and to relate these to microphysical models and the results of the MAGIC rocket project.

Arctic study of tropospheric aerosols, clouds and radiation (ASTAR 2004)

Radovan Krejci, Ann-Christine Julin, Thorsten Mauritsen, Gunilla Svensson, A. Herber and O. Schrems (Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven, Germany), R. Treffeisen, R. Neuber, C. Ritter and K. Hara (Alfred-Wegener-Institut für Polar- und Meeresforschung, Potsdam, Germany), T. Yamanouchi (National Institute for Polar Research, Tokyo, Japan), J. Ström (ITM – Air Pollution Laboratory, Stockholm University), S. Yamagata (Hokkaido University, Graduate School of Engineering, Sapporo, Japan), A. Minkin (German Aerospace Center, Institute for Physic of Atmosphere, Wessling, Germany), A. Schwarzenboeck and J.F. Gayet (Université Blaise Pascal/CNRS, France)

See Arctic Studies

ADDITIONAL PUBLICATIONS: ATMOSPHERIC PHYSICS

de Reus, M., P. Formenti, J. Ström, R. Krejci, D. Muller, M.O. Andreae, and J. Lelieveld. 2002. Airborne observations of dry particle absorption and scattering properties over the northern Indian Ocean, Journal of Geophysical Research - Atmospheres, 107 (D22), 8002

Gayet, J.F., F. Auriol, A. Minikin, J. Ström, M. Seifert, R. Krejci, A. Petzold, G. Febvre, and U. Schumann. 2002. Quantitative measurement of the microphysical and optical properties of cirrus clouds with four different in situ probes: Evidence of small ice crystals, Geophysical Research Letters, 29 (24), art. no. 2230

Krejci, R., J. Ström, M. de Reus, P. Hoor, J. Williams, H. Fischer, and H.-C. Hansson. 2003. The evolution of aerosol properties over the rainforest in Surinam, South America observed from aircraft during the LBA-CLAIRE experiment, Journal of Geophysical Research, 108 (D18), paper #: 4561 doi: 10.1029/2001JD001375

Krejci, R., J. Ström, M. de Reus, and W. Sahle. 2004a. Single particle analysis of the accumulation mode aerosol over the northeast Amazonian tropical rain forest, Surinam, South America, Atmospheric Chemistry and Physics Discussion, 4, 533-568

Krejci, R., J. Ström, M. de Reus, J. Williams, H. Fischer, M.O. Andreae, and H.-C. Hansson. 2004b. Spatial and temporal distribution of the atmospheric aerosols in the lowermost troposphere over the Amazonian tropical rainforest, Atmospheric Chemistry and Physics Discussion, 4, 3565-3606

Minikin, A., A. Petzold, J. Ström, R. Krejci, M. Seifert, P. van Velthoven, and U. Schumann. 2003. Aircraft observations of the upper tropospheric fine particle load in the northern and southern hemispheres at midlatitudes, Geophysical Research Letters, 30 (10), 1503, doi: 10.1029/2002GL016458

Petelina, S., Murtagh, D. and Rodhe, H. 2003. Potential of Gome data in the oxygen A-band for aerosol remote sensing. Report AP-41 International Meteorological Institute in Stockholm, Department of Meteorology, Stockholm University, Stockholm, Sweden

Seifert, M., J. Ström, R. Krejci, A. Minikin, A. Petzold, J.-F. Gayet, H. Schlager, H. Ziereis, U. Schumann, and J. Ovarlez. 2004a. Aerosol-cirrus interactions: A number based phenomenon at all?, Atmospheric Chemistry and Physics, 4, 293-305

Seifert, M., J. Ström, R. Krejci, A. Minikin, A. Petzold, J.-F. Gayet, H. Schlager, H. Ziereis, U. Schumann, and J. Ovarlez. 2004b. Thermal stability analysis of particles incorporated in cirrus crystals and of non-activated particles in between the cirrus crystals: Comparing clean and polluted air masses, Atmospheric Chemistry and Physics, 4, 1343-1353

Seifert, M., J. Ström, R. Krejci, A. Minikin, A. Petzold, J.-F. Gayet, U. Schumann, and J. Ovarlez. 2003. In-situ observations of aerosol particles remaining from evaporated cirrus crystals: Comparing clean and polluted air masses, Atmospheric Chemistry and Physics, 3, 1037-1049

Ström, J., M. Seifert, B. Kärcher, J. Ovarlez, A. Minikin, J.-F. Gayet, R. Krejci, A. Petzold, F. Auriol, W. Haag, R. Busen, U. Schumann, and H.-C. Hansson. 2003. Cirrus cloud occurence as function of ambient relative humidity: A comparison of observations from the Southern and Northern Hemisphere midlatitudes obtained during the INCA experiment, Atmospheric Chemistry and Physics, 3, 1807-1816

Williams, J., M. de Reus, R. Krejci, H. Fischer, and J. Ström. 2002. Application of the Variability-Size relationship to atmospheric aerosol studies: Estimating aerosol lifetimes, Atmospheric Chemistry and Physics, 2, 133-145

ARCTIC STUDIES

The Polar Regions are the primary heat sinks for the global atmosphere and the Arctic Ocean with its sea ice is a major component of the global climate system. The sea ice exerts a strong control of low-level atmospheric conditions and plays a major role in regulating fluxes of energy and matter at the surface, across the ocean/atmosphere interface. In spite of a considerable effort, there is not yet a clear understanding of several feedback mechanisms within the Arctic climate system, involving for example ice, turbulent fluxes, aerosols, clouds, radiation and marine biology. Consequently, current climate models perform poorly in the Arctic and the uncertainty in scenarios of future climate is larger here than elsewhere. The amount of empirical data on Arctic climate processes is inadequate for a proper description of them in climate models. Long-term monitoring of Arctic climate from space-borne instruments also suffers from a lack of ground-truth measurements for validation and development of new improved inversion algorithms.

The work on Arctic climate processes at the institute is based on the expertise in boundary layer and mesoscale meteorology and in chemical meteorology. It has strong foci on the interaction between marine biology – aerosol – cloud formation, and between aerosol formation – boundary-layer fluxes – radiation – clouds. A very strong component of this research evolves around the organization of icebreaker-based field experiments to the central Arctic basin, where institute has an internationally leading role. There are also modelling activities within the ARCMIP program and larger-scale dynamics studies using large-scale model (ERA-40) results.

Arctic Climate Impact Assessment

Erland Källén, Vladimir Kattsov (Main Geophysical Observatory, St Petersburg, Russia), Gunilla Svensson

The Arctic Climate Impact Assessment (ACIA) summarizes our current knowledge regarding Arctic climate change and present as well as possible future effects on Arctic flora, fauna, fisheries, infrastructure and health aspects. The assessment has been made by an international group of scientists coming from a wide range of disciplines. Atmospheric scientists, oceanographers, biologists, engineers, medical doctors and social scientists have been working together to make a comprehensive assessment of climate change in the Arctic. Scientists from MISU have mainly been involved in the chapter dealing with scenarios for future climate change and a discussion of physical processes relevant to the Arctic climate system.

The IPCC A2 and B2 scenarios have been used as a baseline for the assessment of future Arctic climate change, it is found that warming in the Arctic will be much larger than global mean warming rates. It is also found that the natural variability in the Arctic area is large compared with many other parts of the globe, the signal to noise ratio in the Arctic is thus not as strong as has been assumed in previous assessments. Consequences for glacial melting, tree growth, permafrost areas, plants and animals, infrastructure and many other aspects of the Arctic environment are investigated in the report.

References

Kattsov, V. and Källén, E. 2004. ACIA Chapter 4: Future Changes of Climate: Modelling and Scenarios for the Arctic Region. In Arctic Climate Impact Assessment (In Print)

Impact of large-scale dynamic changes on Arctic climate

Rune Grand Graverssen, Michael Tjernström and Erland Källèn

While it is clear that the Arctic is warming faster than the global average, there are several hypotheses to explain this fact. For example, it is believed that changes in the albedo caused by changes in the snow and ice coverage have contributed to the larger warming of the Arctic than elsewhere. In this project we attempt to estimate the possible impact of changing mid-latitude large-scale circulation on the Arctic Surface Air Temperature (SAT) trend. The data we used comes from the European Center for Medium range Weather Forecast (ECMWF) reanalysis (ERA40). We calculated two different indicators of large-scale atmospheric circulation: The vertically integrated total northward flux of energy across 60°N, and the so-called Arctic Oscillation index, AO. These indexes are then correlated to a SAT trend defined as the circumpheral averaged trend in SAT, from the pole to a given south-ward latitude. We have used the time series from 1958 to 2001, thus farther in time than many other studies.

The results show that a significant part of the mean Arctic SAT trend is explained by the northward energy trans-port. The northward energy transport also shows a consistently increasing trend since the 1970's. In contrast to many previous studies that have pointed to links between the AO and various aspects of the Arctic climate, we see no significant correlation between the mean Arctic SAT trend and the AO. Moreover, the previously increasing AO trend, that has been proposed to be an inherent feature in a greenhouse-warming climate, is found to be broken for the last few years of the time series. Thus, although the AO probably remains an important indicator for various aspects of the large-scale atmospheric circulation, its importance for the Arctic SAT development is probably less significant than previously believed.

Arctic Regional Modeling – ARCMIP

Michael Tjernström, Mark Žagar, Gunilla Svensson and Johannes Kalsson, Anette Rinke and Klaus Dethloff (Alfred Wegner Institute, Germany), John Cassano (CIRES, University of Colo-rado, Boulder, USA), Susanne Pfeifer and Tido Semmler (MPI for Meteorology, Germany), Klaus Wyser and Colin Jones (SMHI)

ARCMIP (the Arctic Regional Climate Model Intercomparison Project, http://curry.eas.gatech.edu/ARCMIP/index.html) aims to improve numerical simulations of regional Arctic climate, and to improve the description of im-portant Arctic climate processes in global models. The primary ARCMIP activities focus on coordinated simulations with different regional climate models, using the same horizontal resolution and boundary conditions. Using regional modeling facilitates controlled simulations of the local and regional climate by providing accurate analy-ses as lateral boundary conditions. This also makes possible a direct comparison with observations. Results from the models are intercompared, and compared to and evaluated using in situ and satellite measurements and data from field experiments. With a reasonably controlled background climate, imposed by analyzed boundary condi-tions, remaining errors must be due mostly to regional-model deficiencies. The first ARCMIP intercomparison project uses data from the SHEBA (Surface Heat Budget of the Arctic Ocean) ice-drift experiment in 1997/1998.

This project focus on the lower troposphere and surface fluxes, and uses results from six ARCMIP models. In general, the results confirm that the model domain is sufficiently small that the large scale dynamics is constrained by the boundary conditions. Low-level temperature and humidity, and surface pressure agree well with the observations. Wind speed follows the observed temporal development but with different systematic biases in the models. In some cases these biases are consistent with a bias in surface friction, but not in all models. There are relatively large absolute errors in the surface fluxes, but the correlations to the observations are acceptable. Annual average errors in turbulent heat fluxes are small but only because the fluxes are small and the correlation to the observations is insignificant. Accumulated heat flux errors are very large, an order of magnitude larger than the observed accumulated fluxes. Low-level (surface to about 1 km) biases are much larger than errors in the free troposphere, and low clouds are very well correlated to errors in low-level moisture.

References

Tjernström, M., M. Žagar and G. Svensson. 2004. Model simulations of the Arctic atmospheric boundary layer from the SHEBA year. AMBIO, 33, 221-227

Tjernström, M., M. Žagar, G Svensson, J Cassano, S. Pfeifer, A. Rinke, K. Wyser, K. Dethloff, C. Jones and T. Semmler. 2005. Modeling the Arctic Boundary Layer: An evaluation of six ARCMIP regional-scale models with data from the SHEBA project. Boundary-Layer Meteorology (In Press)

Arctic study of tropospheric aerosols, clouds and radiation (ASTAR 2004)

Radovan Krejci, Ann-Christine Julin, Thorsten Mauritsen, Gunilla Svensson, A. Herber and O. Schrems (Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven, Germany), R. Treffeisen, R. Neuber, C. Ritter and K. Hara (Alfred-Wegener-Institut für Polar- und Meeresforschung, Potsdam, Germany), T. Yamanouchi (National Institute for Polar Research, Tokyo, Japan), J. Ström (ITM – Air Pollution Laboratory, Stockholm University), S. Yamagata (Hokkaido University, Graduate School of Engineering, Sapporo, Japan), A. Minkin (German Aerospace Center, Institute for Physic of Atmosphere, Wessling, Germany), A. Schwarzenboeck and J.F. Gayet (Université Blaise Pascal/CNRS, France)

The ASTAR 2004 measurement campaign was performed in May/June 2004 in the vicinity of Svalbard in order to investigate the transition period from Arctic spring to Arctic summer aerosol conditions. Several flights were designed to link the airborne in-situ observation with ground based measurements in the Ny-Ålesund area. For the Arctic, the main focus of the project is to provide an observational over-determined data set, which is necessary to improve the assessment of the aerosol direct and indirect effects on the Arctic radiative balance. This is achieved by utilizing unique aircraft instrumental payload, addressing both aerosol and cloud microphysical properties in connection with ground-based and satellite observations. Obtained data will be incorporated into AWI regional climate model HIRHAM.

The main objectives of the projects are: 1) Determination of the vertical structure of the chemical, physical and optical properties of Arctic aerosol particles, including radiative closure between observed and calculated aerosol properties (direct aerosol climate effect) 2) Investigation of cloud microphysical and optical properties in the Arctic as a function of different tropospheric aerosol load and the regional extend of aerosol and cloud fields (indirect aerosol climate effect)

To reach the scientific objectives, an extensive aerosol and cloud microphysics payloads were deployed onboard of the German Dornier 228 (POLAR 4 and POLAR 2) airplanes operated by AWI, Bremerhaven, Germany. Various remote sensing and aerosol in-situ measurement systems, including for example sun photometer, integrating nephelometer, particle soot absorption photometer, optical particle counter, several condensation particle counters, DMPS, V-TDMA/DMPS and aerosol filters collected for later IC and single particle analysis were deployed onboard of the POLAR 4 airplane. Adequate cloud microphysics payload together with airborne LIDAR were operated onboard of POLAR 2 airplane.

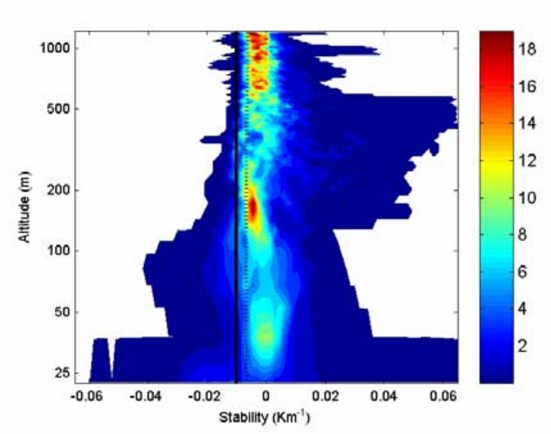
More details can be found at the project website: http://www.awi-bremerhaven.de/www-pot/astar/public/astar2004.html

Vertical structure of the arctic boundary layer during AOE2001

Michael Tjernström, Ola Persson (NOAA-ETL/CIRES), and Mike Jensen (University of Colorado/CIRES)

During the AOE-2001, July 5 to August 21, 2001, different aspects of the vertical structure of the lower tropo-sphere were measured with several different instrument systems. A scanning microwave radiometer monitored the temperature profile from the surface to about 1 km at a temporal resolution of a few minutes. The temperature pro-files are on average slightly stable closest to the surface, then moist neutral through the bulk of the boundary layer up to a capping inversion. There are often multiple inversions but there is usually one main inversion that during advection of air from beyond the ice edge may become very strong, while surface inversions are usually weak.

The top of the low clouds was monitored with cloud radar. In contrast to the mid-latitude or subtropic cloud-capped marine boundary layer, cloud tops in the Arctic summer frequently resided well into the capping inversion layer, rather than to coincide with the inversion base. Also contrary to more southern marine boundary layers, specific humidity (from soundings) across the main capping inversion often increased with height, in particular in cases with advection of air from open ocean south of the ice edge. This means that both entrainment and surface fluxes are sources of moisture to the boundary layer, contributing to persistently very moist conditions and low-intensive precipitation. Contrary to expectations, the wind speed profiles (from wind profiler, sodar and tethered and free-flying soundings) showed that low-level wind jets were relatively rare.



Contours (color) of probability of vertical temperature gradient as a function of height. Solid and dashed lines are dry and moist adiabatic lapse rates respectively.

References

Tjernström, M., C. Leck, P. O. G. Persson, M. L. Jensen, S. P. Oncley and A. Targino. 2004. The summertime Arctic atmosphere: Meteorological measurements during the Arctic Ocean Experiment (AOE-2001). Bulletin of the American Meteorological Society, 85, 1305-1321

Tjernström, M., C. Leck, P. O. G. Persson, M. L. Jensen, S. P. Oncley and A. Targino. 2004. Experimental equipment: A supplement to the summertime Arctic atmosphere: Meteorological measurements during the Arctic Ocean Experiment (AOE-2001). Bulletin of the American Meteorological Society, 85, 1322-1322

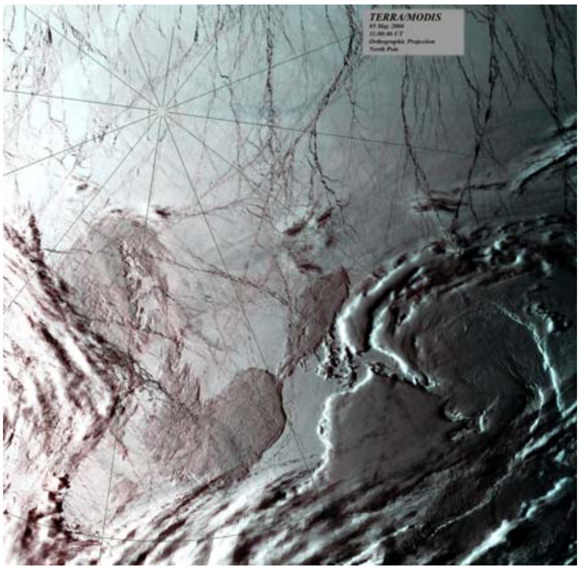
Tjernström, M. 2005. The summer Arctic boundary layer during the Arctic Ocean Experiment 2001 (AOE-2001). Boundary-Layer Meteorology (In Press)

Wave flow simulations over Arctic leads

Thorsten Mauritsen, Gunilla Svensson and Branko Grisogono (Zagreb University, Croatia)

The Arctic Ocean is covered with ice throughout the year. However, wind stress and divergent ocean currents generate long cracks in the ice called open leads. These are typically a few kilometers wide and hundreds of kilometers long. An example is shown in the figure. We investigate the flow over Arctic leads using a mesoscale numerical model under idealized conditions, typical of both summer and wintertime.

We find that Arctic leads may be the source of standing atmospheric internal gravity waves during both seasons. The summertime wave may be compared with the wave generated by a small ridge, however with the phase reversed. The mechanism for exciting the wave is found to be the internal boundary layer developing due to the horizontal variations in surface temperature and roughness length. During the more exploratory wintertime simulations, with substantial temperature difference between the lead and the ice surface, we find that secondary circulations and intermittent wave-breaking may occur. The effects of the lead appear far downstream.



A satellite picture from the North Pole region. White is thick ice, while open or recently refrozen leads show up as gray or black. The irregular shapes in the lower half of the picture are clouds.

Temporal variability in the AOE2001 Arctic boundary layer

Michael Tjernström, Thorsten Mauritzen, Ola Persson (NOAA/ETL) and Carmen Nappo (NOAA/ATDD)

Temporal variability in the Arctic boundary layer is fundamentally different compared to the mid-latitude and sub-tropical boundary layer, where most of the empirical evidence on boundary-layer processes has been collected.

The diurnal cycle, that helps shape the vertical boundary-layer structure farther south, is mostly absent in the Arctic. In Arctic summer, there is a in fact a small diurnal cycle in solar radiation, but the surface-control of low-level temperature and humidity by the melting/freezing processes is so strong that there are no average diurnal trends in either of these. However, the diurnal cycle in radiation is systematically skewed to the highest values a few hours before local noon. This is consistent with systematically lower cloud bases and poorer visibility during mid-day to early afternoon. The wind speed is also somewhat lower during this period, which raises the question if the stability is more well-mixed during this time of the day.

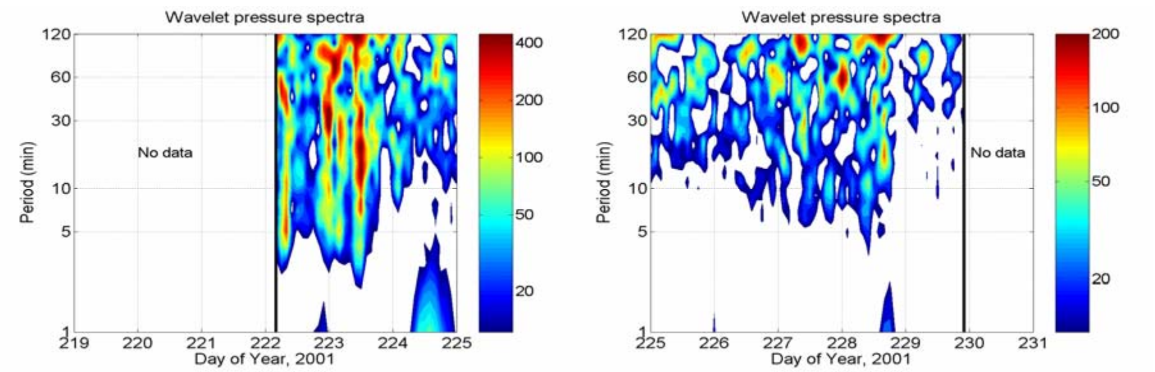
On a shorter time scale, turbulence spectra during certain periods showed significant energy at low frequency, around one or a few hours. This appeared organized; longer periods with high low-frequency energy were followed by long periods without. High energy at low frequency was independent of level of proper turbulence. When this was high, a pronounced spectral gap thus appeared, in particular in the crosswind spectra, but else low-frequency energy could be high also when turbulence was weak, as for example in light-wind conditions. Also on a time scale of hours, microbarograph records show significant high-frequency variability in surface pressure. This usually starts as low-frequency and cascades to higher frequency in time. A wavelet analysis was used to separate out sinusoidal-like disturbances from e.g. frontal passages and other variations. During at least nine episodes during two weeks, there were signs that can be interpreted as gravity-wave-like disturbances and on at least two occasions there appears to be some wave breaking, possibly by Kelvin-Helmholtz waves.

References

Tjernström, M., C. Leck, P. O. G. Persson, M. L. Jensen, S. P. Oncley and A. Targino. 2004. The summertime Arctic atmosphere: Meteorological measurements during the Arctic Ocean Experiment (AOE-2001). Bulletin of the American Meteorological Society, 85, 1305-1321

Tjernström, M., C. Leck, P. O. G. Persson, M. L. Jensen, S. P. Oncley and A. Targino. 2004. Experimental equipment: A supplement to The summertime Arctic atmosphere: Meteorological measurements during the Arctic Ocean Experiment (AOE-2001). Bulletin of the American Meteorological Society, 85, 1322-1322

Tjernström, M. 2005. The summer Arctic boundary layer during the Arctic Ocean Experiment 2001 (AOE-2001). Boundary-Layer Meteorology (In Press)



Time-frequency contour plot of wavelet spectra from one microbarograph sensor. Note the four distinct periods: 1) up to DOY 224, with high amplitude short wave activity; 2) DOY 224 – 227, with less activity at all frequencies; 3) DOY 227 – 229, again with higher high-frequency activity, and; 4) DOY 227 and onwards, with almost no activity. Color scale is logarithmic, in μbar^2.

Nordic Seas 2002; a scientific synthesis of the field experiment conducted from the R V Knorr and the ice-breaker Oden April to June 2002

Johan Nilsson, in external collaboration with Göran Björk (Göteborg University), Bert Rudels (Finnish Marine Research Institute) and Peter Winsor (Woods Hole Oceanographic Institution)

The low-saline cold East Greenland Current (EGC) funnels out the bulk of the Arctic freshwater surplus to the North Atlantic. Due to severe ice and weather conditions prevailing in the Greenland Sea, the freshwater transport in the EGC is poorly known. One aim of the present project is to derive a unique late-winter estimate of the freshwater transport in the EGC based on data collected during the Swedish Arctic Ocean Expedition 2002. The available data set consists of hydrography and ADCP current observations in eight transects of the EGC, from the Fram Strait in the north to the Denmark Strait in the south. In combination with theoretical and numerical studies, the data will be further used to explore the mechanisms that confine the EGC to the continental slope. This confinement is of relevance for the overall stability of the circulation in the Nordic Seas as it permits the warm saline Atlantic water flowing poleward in the eastern Nordic Seas to be transformed into cold high-saline deepwater.

References

Rudels, B., G. Björk, J. Nilsson, P. Winsor, I. Lake, and C. Nohr. 2004. The interaction between waters from the Arctic Ocean and the Nordic Seas north of the Fram Strait and along the East Greenland Current: results from the Arctic Ocean-02 Oden expedition. J. Mar. Syst., doi:10.1016/j.mar.sys.2004.06.008

The properties of the surface microlayer of the open leads and the ocean mixed layer in the central arctic basin pack ice area

Caroline Leck, Keith Bigg, Patricia Matrai, Johannes Knulst, Kalle Olli, Lars Tranvik, Paul Wassman and Johanna Ikavälko

Collection of the surface microlayer (<100µm thick) of the open leads during the month of August between latitudes 88 and 89°N (AOE-2001) was accomplished by hydrophilic teflon rollers ahead of radio-controlled boats. The particulate content of samples of the surface microlayer water was examined by transmission electron microscopy. Concentrations were extremely numerous, ranging from $210^7 ml^{-1}$ to more than $10^{14} ml^{-1}$ although bacterial counts made in the same samples varied by only about 50%. Size distributions of the particles were also very variable with modal diameter sizes of 10 nm in some samples and 50 nm in others, the 50 nm particles appearing to be clusters of the 10 nm ones. The particulates appeared to have very similar characteristics to the "microcolloids" observed in bulk seawater in lower latitude oceans. X-ray analyses of the elements with atomic numbers >16 showed all signals to be weak, suggesting a mainly organic composition. One other feature of the particulates was that they were joined together by a diffuse material, which had properties entirely consistent with those of exopolymer secretions (EPS) of algae and bacteria. EPS gels consist of large, highly surface-active and highly hydrated (99% water) molecules. They are polysaccharides to which other organic compounds such as proteins, peptides and amino acids are readily bound. EPS gels can collapse due to exposure to ultraviolet light, acidification. The surface microlayer also showed, besides particulate matter and bacterias, elevated concentrations of proteins, and dissolved organic substances.

The linkage between elevated levels of bulk water chlorophyll a and particulate dimethyl sufonium propionate, DMSP, (both indicators of phytoplankton biomass), proteins, and bacterial abundance is most likely a reflection of the ongoing planktonic production and cycling, as well as the input of ice algae. Ice algae were present in high concentrations, mostly at the bottom of the ice floe, and may have affected the levels of particulate organic matter observed. Most of the phytoplankton was present as small, flagellated forms, while most of the mesozooplankton biomass was composed of copepepods. Production of specific compounds, such as DMSP and DMS, was constrained to the surface mixed layer (0-20 m). Nonetheless, carbon export was measured past 50m, staying fairly constant throughout the water column for the duration of the drift. Bulk water primary and bacterial production was measurable but not high, always highest in the upper 5m of the water column.

References

Bigg, E.K., C. Leck and L. Tranvik. 2004. Particulates of the surface microlayer of open water in the central Arctic Ocean in summer, Marin Chemistry, 91, 131-141

Biogenic particles over the central Arctic Ocean

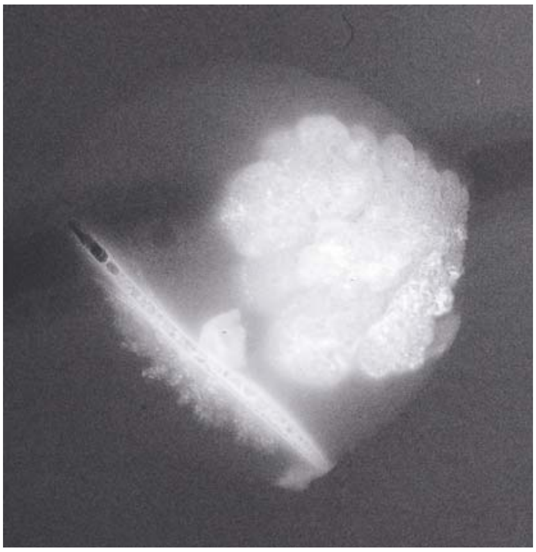
Caroline Leck and Keith Bigg

Transmission electron microscopy photographs of airborne particles are compared with those of particles found in the surface microlayer of the open water between ice floes during the summer between latitudes 88 and 89°N (AOE-2001). The similarity in morphology (closely resembling microcollids or "virus like particles"), physical properties, X-ray spectra and a chemical reaction of the numerous aggregates and their building blocks and of bacteria and other micro-organisms found in both, strongly suggests that the airborne particles were ejected from the water by bursting bubbles. On average, during the five weeks spent in the pack ice region, surface microlayer-derived particles represented more than one-half of the collected airborne submicrometre particle and more than four-fifths on sunny days when melting of the fringes of the ice floes was observed. On all days surface microlayer-derived particles dominated the population below 70 nm in diameter, the Aitken mode.

The shape of the size distribution of aggregates in the air was very similar to that in the water, each with a well-defined Aitken mode but shifted towards smaller sizes. Diffuse electron-transparent material joining and surrounding the particulates in both the air and water was shown to have properties consistent with the highly surface-active exopolymer secretions, EPS, of microalgae and bacteria in the water. The EPS collapse under the influence of ultraviolet light and acidification. Their lifetime in the atmosphere is therefore limited and is a sufficient reason why the airborne aggregate size distribution shifted to a smaller modal diameter (30nm instead of 50nm).

Fresh aggregates with EPS gel on them could act as CCN directly because of the gels strong surface-active properties. Those that have lost their gel could still act as sites for condensation of the oxidation products of DMS. Evidence that this happens is the detection of presence of insoluble marine microcolloids in most (50-90% of total number counted) of the predominantly sulphate particles. Their acquistion of sulfuric acid provides a much more direct and faster path to CCN staus than having to grow from nucleated particles. Figure 1 (if wanted) shows examples of microcolloids within sulfate particles and other types containing a core microcolloid.

With this new picture on the evolution of the remote Arctic aerosol, DMS concentration will determine the mass of sulfate produced but will have only a minor influence on the number of CCN and thus cloud droplets, which will be dictated by the number of airborne particles originating in the surface microlayer of the open leads. This invalidates the “CLAW” hypothesis by Charlson and coworkers in 1987 that DMS oxidation products alone produces particles of CCN size and poses a stronger possible link between marine biology, cloud properties and climate than is provided by DMS alone.



A microcolliod aggregate particle collected in the atmosphere surrounded by EPS gel. It also contains a bacterium attached to a small aggregate possibly detached from the larger one. The DES of the larger aggregate is about 630 nm and assuming that the thickness is equal to the width of the largest component.

References

Leck, C., and E.K. Bigg. 2004. Biogenic particles in the surface microlayer and overlaying atmosphere in the central Arctic Ocean during summer, Tellus B (In Press)

The spatial variability of atmospheric DMS – a model approach

Jenny Mattsson, Caroline Leck and Gunilla Svensson

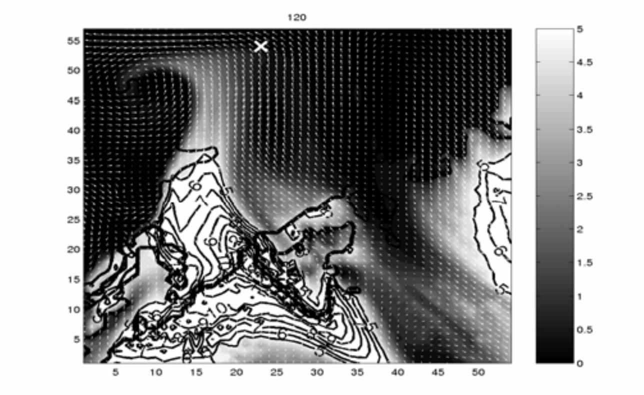
In the high Arctic (north of 80°N), the oxidation products (sulfur dioxide, sulfuric acid and methane sulfonic acid) of dimethyl sulfide (DMS) contribute to cloud formation. These sulfur components can condense on pre-existing aerosols in the atmosphere and thereby take part in CCN activation and hence cloud formation. Past observations in the high Arctic show a large spatial variability of atmospheric DMS. This study has been performed to investigate the extent to which meteorological processes could be the cause of the observed variability during the Arctic Ocean Expedition 2001 (AOE-2001).

We have used the atmospheric part of COAMPS™ (Coupled Ocean/Atmospheric Mesoscale Prediction System), with a resolution of 30 km x 3 km, to simulate the advection of DMS from its source region in the Greenland Sea in over the mostly ice covered pack ice area.

To estimate the sea to air flux of DMS, we use the median value from the observed sea water concentration of DMS, representative for the Greenland Sea, and a transfer velocity calculated according to the Liss and Merlivat, 1986, relationship. The transfer velocity is dependent on sea surface temperature, salinity and wind speed, and is described in a combination of three linear segments having breaking points at 3.6 and 13 ms^{-1}. The transfer velocity was calculated in each grid point, using sea surface temperature and wind speed from the model.

Combining DMS data collected during AOE-2001, with time of advection from the open sea, calculated from trajectories and ice maps, it was possible to estimate the DMS turnover time. An average turnover time of 1.6 days was used to simulate the chemical loss rate of DMS in over the pack ice area. To define the border between the open sea and the ice edge a satellite based ice cover was used in the model. According to previous estimates, based on observations, the sea to air flux of DMS over the pack ice area was set to zero.

Our results show that DMS is advected in confined plumes from the source region as depicted in the figure. Concentrations within the pack ice region will therefore depend heavily on the location of the point of observation, and could at least partly explain the observed spatial variability at any given location. However it is suggested that meteorological parameters, such as wind speed seems to have the largest impact on the observed spatial variability of atmospheric DMS.



Snap shot of DMS advecting in narrow plumes from the source region after 120h of simulated time. DMS concentration over the pack ice in gray, and over open sea as thin lines where the numbers shows the DMS concentration in nmol m^{-3}. Thick black lines indicate the border between the pack ice region and the open sea. The white cross indicates the locaton of the Swedish icebreaker Oden.

New evidence of fog-related aerosol sources over the arctic pack ice in summer

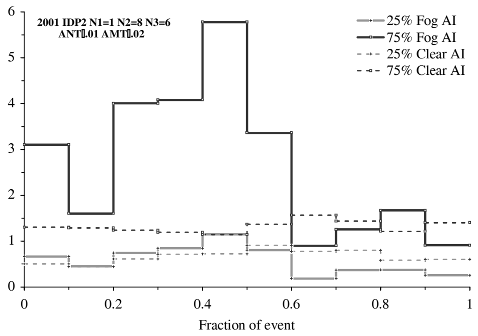
Jost Heintzenberg, Caroline Leck and Michael Tjernström

Fogs and low clouds are traditionally mainly seen as particle sinks due to in-cloud and sub-cloud scavenging processes. Only a few observations indicate gas-to-particle formation in the vicinity of clouds. However, no mechanisms have been deduced from these studies that could explain the new particle formation in the Aitken diameter range (25-70 nm) as hypothesized by Leck and Bigg in 1999 in the summer Arctic.

To search for evidence of a fog-related aerosol source in the high Arctic summer the present study covers aerosol size distribution data taken during two icebreaker expeditions in the summers of 1996 (AOE-96), and 2001 (AOE-2001). The main part of the working regions of both expeditions was the pack-ice-covered high Arctic north of 83°N for which no other aerosol data exist. The aerosol-physical instrumentation detected particles from 4 nm to 45 µm diameter and included a DMPS, an APS, and an FSSP-100. With the latter instrument fog episodes could be delineated in the aerosol database. For further interpretation the 41-channel submicrometer number size distributions were aggregated into a maximum of four lognormal size distributions called ultrafine, Aitken, accumulation and coarse modes.

Two approaches were followed, (1): time-independent size-dependent frequencies of occurrence of modal concentrations during fogs with different thresholds of drop concentrations were compared to respective data from fog-free periods. With increasing fog intensity modes in interstitial particle number concentrations appeared in particular in the size range around 80 nm that was nearly mode-free in clear air, (2): in a dynamic approach, fog periods were defined objectively with six parameters including thresholds of drop number and LWC, length of fog period and, importantly, the length of fog-free period after fog dissolution. The result is depicted in the figure.

When including 80 fog-free post-fog minutes average Aitken mode concentrations increased strongly above their respective fog-period-medians in both years before maximum drop numbers were reached during the fog. We interpret the results of both approaches as strong indications of fog-related aerosol source processes as discussed in Leck and Bigg in1999 that need to be elucidated with further data from dedicated fog experiments in future Arctic expeditions in order to understand the life cycle of the aerosol over the high Arctic.



Normalized median modal concentrations for the Aitken mode (AI) as a function of the fraction of fog events in 1996 satisfying the fog criteria stated in the text and with travel times from the ice edge > 24 h. Top thick line stands for the 75 percentile whereas the lower thick line stands for the 25 percentile. Thin dashed lines give the corresponding statistical parameters for clear periods of the same lengths.

Evidence of a surface source of ultra fine aerosol particles in the Arctic Ocean pack ice during summer

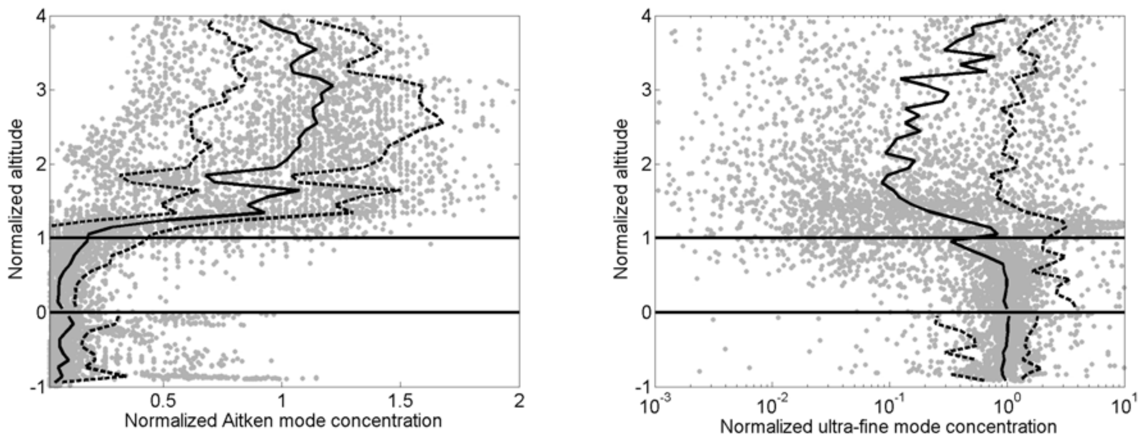
Caroline Leck, Keith Bigg, Erik Swietlicki (Lund University, Sweden) and Michael Tjernström

Vertical and horizontal profiles of aerosol particle concentrations in several size ranges were measured from 35 helicopter flights during the Arctic Ocean Expedition in July-August 2001 (AOE-2001). Most measurements were performed at latitudes north of 87^o over broken pack ice with ice-free leads covering about 15% of the ocean surface. The aerosol particle size concentrations were measured at 1 Hz in several size ranges using two Condensation Particle Counters (CPCs) and an Optical Particle Counter (OPC). The particle concentrations of ultra fine particles (diameters between 3-15 nm) were derived by taking the difference between the two CPCs operating with different lower cut-off sizes. Due to flight-safety regulations, in-cloud flights in iceing conditions were prohibited. Instead flights were conducted in brief periods with clearing low-level clouds. A sounding was always conducted in connection to each flight. Moreover, data from a scanning microwave radiometer, a cloud base lidar and a cloud radar contributed to estimates of cloud and inversion base and cloud top immediately before and after each flight.

In general the ultra fine particle concentrations were typically a few hundred per cm^{-3}, but reached as high as 1500 cm^{-3}. Only occasionally signs of elevated particle concentrations in the ultra fine size range were observed at higher altitudes. These ultra fine particles were observed at low wind speeds during clear-sky or partly clear-sky conditions within the shallow (normally below 150m) boundary layer. This boundary layer was capped with a strong inversion preventing mixing with overlying air. The boundary layer levels of the accumulation mode particles (measured by the OPC) were in general well below 1 cm^{-3}. Such low levels are easily explained by conditions of a very moist boundary layer combined with the absence of strong local sources of accumulation mode particles. On the contrary peaking accumulation mode numbers were found just above the former cloud top.

The figure below depicts the observed results from six selected flights including some 30 individual profiles. The air sampled had spent a minimum of five days over the pack ice. Observed levels of accumulation mode particles were typically about one order of magnitude lower in the two layers closest to the surface (the proper boundary layer and the former cloudy layer), than immediately above the cloud top with the recognized feature of a typical distinct maximum. The levels were on average slightly enhanced within the proper boundary layer, below the capping inversion, than in the upper former cloud layer. The observed ultra fine particle levels showed to be most elevated and roughly constant in the layers reaching from the surface to the cloud top. The record in the cloud-layer above the inversion base showed a slightly higher degree of variability. In the free troposphere above the cloud top there was a general decrease in the ultra fine particle concentrations. Note the high degree of scatter observed between individual profiles. The ultra fine particles within the boundary layer were also confined horizontally. During two of the flights, a meter-sharp horizontal border separating regions of high and zero ultra fine particle concentrations was found. Since these ultra fine particles have limited lifetime within the shallow boundary layer (hours), the observations clearly point to a surface source of particles. The limited horizontal extent of the ultra fine particle "cloud" also indicates that the source is confined to certain regions of pack ice or certain air masses.

From these observations it is suggested firstly that the ultra fine particles are most likely to originate from gas to particulate conversion and secondly that the nucleating material seems to be derived from the surface of the open leads. An independent but consistent result was the necessary condition of a biologically active open lead surface microlayer for atmospheric nucleation to occur. The hardest problem to specify the nature of the nucleating material is remaining although test on the particles during nucleation events is supportive but not enough conclusive to single out the amino acid L-Methionine as the nucleating agent.



Profiles of accumulation mode and ultra fine mode particles collected during AOE-2001. The vertical axis is scaled so that the two lowest layers, from the surface to the inversion base and from the inversion base to the cloud top, respectively, both have unity thickness. The uppermost layer represents the free troposphere.

Importance of submicrone surface active organic aerosols for pristine Arctic clouds – a model study

Ulrike Lohmann (Dalhousie University, Halifax, Canada) and Caroline Leck

In searching for a relationship between the properties of the summer high Arctic aerosol north of 80° and its ability to form cloud condensation nuclei (CCN), given the presence of a multi phase (inorganic/organic) aerosol system, past calculations showed by assuming equilibrium Köhler theory and measured number size distribution that other components than sulfate or sea salt, probably organics, depressed the nucleating ability of the particles during cloudy conditions. However, on clear sky days, there were a majority of occasions on which measured CCN concentrations were more numerous than predicted from a pure sulfate/sea-salt composition. Since the Köhler theory cannot take kinetic effects into account, which can cause erroneous results when the competition for water vapor for different size aerosol particles, the cloud nucleation process was instead simulated with a Lagrangian parcel model. These new simulations showed that as the time of advection from the open ocean over the pack ice increased, the relative contribution of an Aitken mode (25 to 70 nm in diameter) to the observed CCN population increased, and a source of Aitken mode particles over the pack ice was required to maintain the CCN population. This activated Aitken mode had to be composed of an external mixture of water soluble inorganic/organic compounds and some almost water insoluble organic material covered with highly surface-active material such as exopolymer secretions (EPS). EPS originates from the open lead surface microlayer. If the Aitken mode consisted just of DMS oxidation products, that are not surface active, the observed CCN population over the inner parts of the pack ice could not be explained.

We therefore have to assume the presence of a larger natural source of particles available for nucleation into cloud droplets than can result from DMS oxidation products alone. If there should be an increase in anthropogenically produced particles in the area at some future date the effect of the presence of activated Aitken mode particles on resulting effective CCN concentrations depends entirely on the relatively spread of supersaturations at which the two groups can form cloud drops. The natural particle population is likely to be active at lower supersaturations than the anthropogenic one, because of the surface active material. In any case, the indirect aerosol effect (added cooling) is enhanced relative to a DMS-oxidation product source of CCN alone.

References

Lohmann, U., and C. Leck. 2004. Importance of submicrone surface active organic aerosols for pristine Arctic Clouds, Tellus B (In Press)

STAFF

STAFF MEMBERS (AS OF DECEMBER 2004)

SCIENTISTS

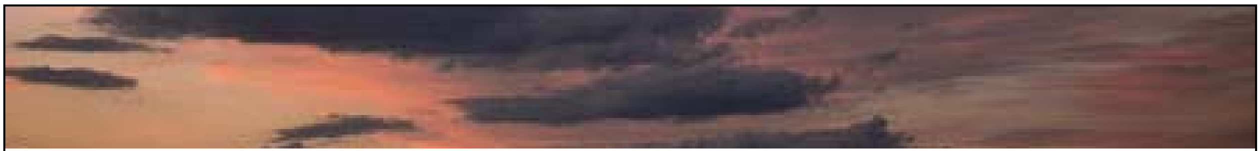
BOLIN, Bert (emeritus)
BROSTRÖM, Göran
DÖÖS, Kristofer
EKMAN, Annica
GLANTZ, Paul
GRANAT, Lennart
GUMBEL, Jörg
GUSTAFSSON, Nils
KREJCI, Radovan
KÄLLÉN, Erland
LECK, Caroline
LEJENÄS, Harald
LUNDBERG, Peter
MOBERG, Anders
NILSSON, Johan
NOONE, Kevin
NYCANDER, Jonas
RODHE, Henning
SIGRAY, Peter
STEGMAN, Jacek
SVENSSON, Gunilla
SÖDERBERG, Stefan
TJERNSTRÖM, Michael
WITT, Georg (emeritus)

RESEARCH STUDENTS

BENDER, Frida
BRANDEFELT, Jenny
ENGSTRÖM, Erik
GRAND GRAVERSEN, Rune
GRANTINGER, Andreas
HEDIN, Jonas
JONSSON, Andreas
JULIN, Ann-Christine
JÖNSSON, Bror Fredrik
KARLSSON, Bodil
KARLSSON, Johannes
KRECL, Patricia
LAUROS, Johanna
LOSSOW, Stefan
MATTSSON, Jenny
MAURITSEN, Thorsten
MEGNER, Linda
MOHAMMAD, Rezwan
MÅRTENSSON, Tomas
MÅRTENSSON, Monica
NILSSON, Jenny
OLIVARES, Gustavo
TARGINO, Admir

ADMINISTRATIVE AND TECHNICAL STAFF

ALBERTS, Birgitta
BJÖRLING, Birgitta
BURGER, Mikael
BÄCKLIN, Leif
DE HAAN, Albert
JOHANSSON, Fredrik
JOHANSSON, Pat
KHAPLANOV, Mikhail
LARSSON, Solveig
LINDSTRÖM, Kristina
MELANDER, Britt-Marie
SÖDERLUND, Jan
TIBERG, Eva
WALBERG, Nils
ÖHRSTRÖM, Agneta



V I S I T O R S

VISITORS

DYNAMIC METEOROLOGY

Andersson, Erik – *ECMWF, Reading, United Kingdom*

Angevine, Wayne – *NOAA Aeronomy Laboratory, Boulder, USA*

Brazdil, Rudolf – *Institute of Geography, Masaryk University of Brno, The Czech Republic*

Chung, Chul – *Scripps Institution of Oceanography, San Diego, USA*

Kalnay, Eugenia – *Department of Meteorology, University of Maryland, College Park, USA*

Kleeorin, Nathan – *Ben Gurion University, Tel-Aviv, Israel*

Luterbacher, Jürg – *Climatology and Meteorology, University of Bern, Switzerland*

Matsuno, Taroh – *Frontier Research System for Global Change, Yokohama, Japan*

Oerlemans, Hans – *Institute for Marine and Atmospheric Research, Utrecht Univ., Utrecht, Netherlands*

Rabier, Florence – *Meteo France, Toulouse, France*

Rogachevski, Igor – *Ben Gurion University, Tel-Aviv, Israel*

Steyn, Douw – *Faculty of Graduate Studies, The University of British Columbia,Vancouver, Canada*

Zagar, Mark – *Meteorological Office, Environmental Agency of Slovenia, Ljubljana, Slovenia*

von Storch, Hans – *Institute of Coastal Research, Geesthacht, Tyskland*

PHYSICAL OCEANOGRAPHY

Caballero, Rodrigo – *University of Chicago, USA*

Davies, Peter – *University of Dundee, United Kingdom*

Dutkiewicz, Stephanie – *Research Scientist, MIT, Cambridge, USA*

Follows, Michael – *MIT, Cambridge, USA*

Grisogono, Branko – *Department of Geophysics, Faculty of Science & Math., Zagreb, Croatia*

Hietala, R. – *Finnish Institute of Marine Research, Helsingfors, Finland*

Huber, Matthew – *Purdue University, West Lafayette, USA*

Laanearu, Janek – *Tallin University of Technology, Tallinn, Estland*

LaCasce, Joseph – *Norwegian Meteorological Institute, Oslo, Norway*

Marchal, Olivier – *Department of Geology and Geophysics, Woods Hole Oceanographic Institution, USA*

Nøst, Ole Anders – *Norwegian Polar Institute, Tromsø, Norway*

Olafsen, Harald – *Department of Physics, University of Iceland*

Pierrehumbert, Ray – *Department of Geosciences, University of Chicago, USA*

Rossby, Thomas – *University of Rhode Island, Kingston, USA*

Sanford, Tom – *Applied Physics Lab and School of Oceanography, University of Washington, USA*

Sambrotto, Ray – *Lamont-Doherty Earth Observatory, Columbia University, New York, USA*

Scott, Jeff – *MIT, Boston, USA*

Stipa, Tapani – *Finnish Institute of Marine Research, Helsingfors, Finland*

Tyler, Robert – *University of Washington, Seattle, USA*

Vang, Einar – *Hoyvik, Föröarna*

Weber, Jan Erik – *Oslo University, Oslo, Norway*

Whitehead, John – *Department of Physical Oceanography, Woods Hole Oceanographic Institution, USA*

Wåhlin, Anna – *Department of Geophysics, Oslo University, Norway*

CHEMICAL METEOROLOGY

Artaxo, Paulo – *Instituto de Fisica, University of São Paulo, Brasil*

Bigg, Keith – *Antarctic Society, Castle Hill, Australia*

Brooks, Ian – *School of Earth and Environment, University of Leeds, United Kingdom*

Brunekreef, Bert – *Institue for Risk Assessment Sciences, University of Utrecht, Netherlands*

Charlson, Robert J – *University of Washington, Seattle, USA*

Das, Ruby – *Regional Research Laboratory, Bhubaneswar, India*

Dyurgerov, Mark – *University of Colorado, Boulder, USA*

Galloway, James – *University of Virginia, Charlottesville, USA*

Heintzenberg, Jost – *Institute for Tropospheric Research, Leipzig, Germany*

Holtslag, Bert – *Meteorology and Air Quality, Wageningen University, The Netherlands*

Intrieri, Janet – *NOAA Environmental Technology Laboratory, Boulder, USA*

Jensen, Michael – *University of Colorado, Boulder, USA*

Karl, Matthias – *Forschungszentrum Jülich, Germany*

Kleeorin, Nathan – *Ben Gurion University, Tel-Aviv, Israel*

Kulshrestha, Umesh – *Indian Institute of Chemical Technology, Hyderabad, India*

Lohmann, Ulrike – *Dept. Physics & Atmos. Science, Dalhousie University, Halifax, Canada*

Selleck, Paul – *CSIRO Atmospheric Research, Aspendale, Australia*

Shepherd, Ted – *Department of Physics, University of Toronto, Canada*

Sørensen, Lise Lotte – *Risø National Laboratory, Roskilde, Denmark*

Tiwari, Suresh – *Indian Institute of Tropical Meteorology, New Delhi, India*

Verlinde, Hans – *Penn State University, USA*

Wisthaler, Armin – *University of Innsbruck, Austria*

ATMOSPHERIC PHYSICS

Covert, David – *University of Washington, Seattle, USA*

Kaiser, Johannes – *Remote Sensing Laboratories, University of Zürich, Switzerland*

Khosrawi, Farah – *Inst. of Stratospheric Chemistry, Jülich, Germany*

Lahoz, William – *Data Assimilation Research Center, University of Reading, U.K.*

De Leeuw, Gerrit – *TNO Physics and Electronics Laboratory, The Hague, Netherlands*

Ogren, John – *NOAA Climate Monitoring and Diagnostics Laboratory, Boulder, USA*

Petelina, Svetlana – *Inst. of Space and Atmospheric Studies, Univ. of Saskatchewan, Saskatoon, Canada*

Plane, John – *University of East Anglia, Norwich, United Kingdom*

Russell, Lynn – *Princeton University, Princeton, USA*

Stevens, Michael – *Naval Research Laboratory, Washington D.C., USA*

F I N A N C E S

FINANCES

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IMI/MISU		
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PHD THESES

PHD THESES 2001-2004

Annica Ekman, 2001, The atmospheric sulfur cycle and its impact on the European climate. A model study

Martin Ridal, 2001, Numerical simulations of the isotopic composition of stratospheric water vapour and methane

Tapani Stipa, 2002, Freshwater, density gradients and biological processes in cold, brackish seas. Aspects of the biogeophysical fluid dynamics characterising the Baltic Sea

Måns Håkansson, 2002, Winds, shear and turbulence in atmospheric observations and models

Paul Glantz, 2002, Aerosol cloud interactions in the marine boundary layers

Radovan Krejci, 2002, Physico-chemical properties of atmospheric aerosols in the tropical troposphere

Michael Norman, 2003, Chemical characteristics of atmospheric aerosols. The influence of natural and man-made sources and sinks

Iréne Lake, 2003, Some aspects of the deep-water flow through the Faroe-Bank channel

Anna Nikolopoulos, 2003, Theoretical and observational aspects on deep-water overflows. With emphasis on the Denmark Strait

Marco Seifert, 2003, Aerosol-cirrus interactions. Comparing clean and polluted air masses

Kristina Eneroth, 2003, Atmospheric transport of carbon dioxide and other trace species in high northern latitudes

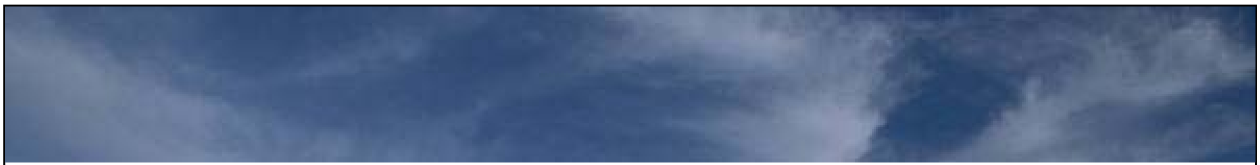
Lars Gidhagen, 2004, Emissions, dynamics and dispersion of particles in polluted air

Stefan Söderberg, 2004, Mesoscale dynamics and boundary-layer structure in topographically forced low-level jets

Nedjeljka Zagar, 2004, Dynamical aspects of atmospheric data assimilation in the tropics

Oskar Parmhed, 2004, Near surface atmospheric flow over high latitude glaciers

Peter Tunved, 2004, On the lifecycle of aerosol particles. Sources and dispersion over Scandinavia



A C R O N Y M S

ACRONYMS

ABC	Atmospheric Brown Clouds
ACC	Antarctic Circumpolar Current
ACE	Aerosol Characterisation Experiment
ACIA	Arctic Climate Impact Assessment
ADM	Atmospheric Dynamics Mission
ADCP	Acustic Doppler Current Profiler
ALOMAR	Arctic Lidar Observatory for Middle Atmosphere Research
AO	Arctic Oscillation
AOE	Arctic Ocean Expedition
AOT	Aerosol optical thickness
AP	Atmospheric Physics (a section of IMI/MISU)
APS	Aerodynamic Particle Sizer
ARCMIP	Arctic Regional Climate Model Intercomparison Project
ASCOS	Arctic Summer Cloud-Surface Study
ASTAR	Arctic Study of Tropospheric Aerosols, Clouds and Radiation
AWI	Alfred Wegener Institute
CABLE	Co-operation Alomar Bi-static Lidar Experiment
CACGP	Commission on Atmospheric Chemistry and Global Pollution
CAD	Composition of Asian Deposition
CANTAT	Canadian Transatlantic Circulation
CAPPS	Charging of Aerosol Particles in the Polar Summer
CCM	Chemistry climate model
CCN	Cloud Condensation Nuclei
CIRES	Cooperative Institute for Research in the Environmental Sciences
CM	Chemical Meteorology (a section of IMI/MISU)
CMAM	Canadian Middle Atmosphere Model
COAMPS	Coupled Ocean/Atmospheric Mesoscale Prediction System
CPC	Condensation Particle Counter
CVI	Counterflow Virtual Impactor
CW	Coastal Waves
DM	Dynamic Meteorology (a section of IMI/MISU)
DMS	Dimethyl Sulfide
DMPS	Differential mobility particle sizer
DMSP	Dimethyl Sufonium Propionate
DNMI	Det Norske Meteorologiske Institutt
DOAS	Differential Optical Absorption Spectroscopy
DSMC	Direct Simulation Monte Carlo technique for rarefied flows
EAPS	Earth, Atmospheric and Planetary Sciences
eARI	enhanced Alomar Research Infrastructure
ECOMA	Existence and Charge state Of Meteoric dust in the middle Atmosphere
ECMWF	European Centre for Medium Range Weather Forecasts
EGC	East Greenland Current

EMULATE	European and North Atlantic daily to MULTidecadal elimATE variability
EPS	Exopolymer Secretions
ERA	ECMF Re-Analysis
ESA	European Space Agency
EUFAR	European Fleet for Airborne Research
FSSP	Forward scattering spectrometer probe
FTS	Fourier Spectrometer
GABLS	GEWEX Atmospheric Boundary Layer Study
GCM	General Circulation Model
GEWEX	Global Energy and Water Cycle Experiment
HIRLAM	High Resolution Limited Area Model
ICSU	International Council of Science
IITM	Indian Institue of Tropical Meteorology
IPY	International Polar Year
ISAC	International Study of Arctic Change
ITM	Institute of Applied Environmental Research
IGBP	International Geosphere-Biosphere Programme
IMI	The International Meteorological Institute in Stockholm
INDOEX	Indian Ocean Experiment
IPCC	Intergovernmental Panel on Climate Change
ITCZ	InterTropical Convergence Zone
JRA	Joint Research Activity
LGM	Last Glacial Maximum
LWC	Liquid Water Content
MAGIC	Mesospheric Aerosols Genesis, Interaction and Composition
MBL	Marine Boundary Layer
MEDCAPHOT-TRACE	Mediterranean Campaign of Photochemical Traces – Transport and Chemical Evolution
MERIS	MEdium Resolution Imaging Spectrograph
MISU	Meteorologiska Institutionen, Stockholms Universitet (Department of Meteorology, Stockholm University)
MIUU	Meteorologiska Institutionen, Uppsala Universitet
MPI	Max-Planck-Institute
MSA	Methane Sulphonic Acid
MSLP	Mean-Sea-Level pressure
NADW	North Atlantic Deep Water
NCAR	National Center for Atmospheric Research, Boulder, USA
NEAQS	The New England Air Quality Study
NRL	Naval Research Laboratory, Washington D.C.
NLC	NoctiLucent Clouds
NOAA	National Oceanic and Atmospheric Administration, USA
OEM	Optimal Estimation Method
OPC	Optical Particle Counter
OSIRIS	Odin Spectrometer and InfraRed Imaging System

RAPIDC	Regional Air Pollution in Developing Countries
RCA	Rossby Centre Atmospheric mldel
RCO	Rossby Center Ocean model
RMR	Rayleigh/Mie/Raman
SAT	Surface Air Temperature
SeaWIFS	Sea viewing Wide Field Sensor
SEI	Stockholm Environment Institute
SHEBA	Surface Heat Budget of the Arctic Ocean
Sida	Swedish International Development Cooperation Authority
SMHI	Swedish Meteorological and Hydrological Institute
SMR	Sub-Millimetre Radiometer
SSH	Sea-Surface Height
SST	Sea Surface Temperature
STEAM	Stratosphere-Troposphere Exchange And climate Monitor
SWECLIM	SWEdish regional CLImate Modelling programme
SWIFT	Stratospheric Wind Interferometer for Transport studies
TA	Transnational Access
THC	ThermoHaline Circulation
TOA	Top of Atmosphere
UT/LS	Upper Troposphere/Lower Stratosphere
V-TDMA	Volatility Tandem Differential Mobility Analyser
WCRP	World Climate Research Programme
WMO	World Meteorological Organization
ZAMM	Zeitschrift für Angewandte Mathematik und Mechanik