Stockholm University

INTERNATIONAL METEOROLOGICAL INSTITUTE IN STOCKHOLM

DEPARTMENT OF METEOROLOGY, STOCKHOLM UNIVERSITY

BIENNIAL REPORT 2013–2014

FRONT COVER

Stereoscopic picture of NLC resulting from Georg Witt's ground-based observations at Torsta (63°N, 15°E), Sweden, in 1958. The photographic pair printed together was taken with two cameras at a distance of 51.5 km. The picture can be viewed through couloured 3-D glasses (blue filter over the right eye, red filter over the left eye). Structures in the clouds are caused by gravity waves and Kelvin Helmholtz instabilities. For details, see the original publication by G. Witt, "Height, structure and displacements of noctilucent clouds", Tellus, 14, 1-18, 1962.

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

BIENNIAL REPORT 1 JANUARY 2013– 31 DECEMBER 2014

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

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

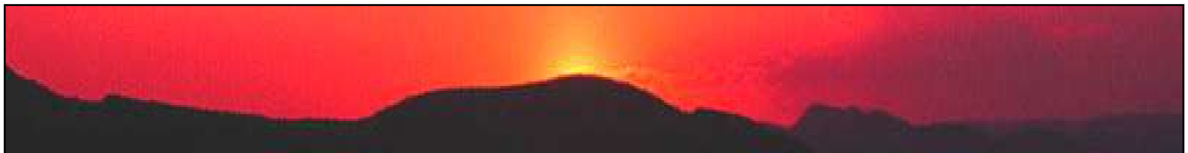
Telefax
Int. +46-8-15 71 85 Nat. 08-15 71 85

E-mail
imi@misu.su.se

Internet
www.misu.su.se

ISSN 0349-0068

TABLE OF CONTENTS



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 also publishes the scientific journal Tellus.

The institute was an independent institute financed by a direct contribution from the Swedish Government until the end of 2009. Since 1 January 2010, IMI is an independent institute at the Department of Meteorology, of which it is an integral part, funded by Stockholm University through the Faculty of Science.

GOVERNING BOARD

Anders Karlqvist, Professor of System Analysis, Appointed by Stockholm University.

Pontus Matstoms, Research Director at the Swedish Meteorological and Hydrological Institute. Appointed by SMHI.

Per Holmlund, Professor of Glaciology, Stockholm University. Appointed by Stockholm University.

Erland Källén, Professor of Dynamic Meteorology, Stockholm University. Appointed by the Board.

Caroline Leck, Professor in Chemical Meteorology. Appointed by the Board.

Anna Rutgersson, Professor in Meterology. Appointed by the Royal Swedish Academy of Sciences.

Jonas Nycander, (Deputy) Director of the Institute. Ex Officio Member.

Rodrigo Caballero, Deputy Director of the Institute. Ex Officio Member.

Secretary of the Board: Albert de Haan, Economist.

DIRECTOR

Jonas Nycander, Professor of Geophysical Fluid Dynamics.

Deputy Director, Rodrigo Caballero, Professor in Climate Modelling.

TELLUS

The international scientific journal Tellus was founded in 1949. It started as a quarterly geophysical journal published by the Swedish Geophysical Society and with professor Carl-Gustaf Rossby as Editor-in-Chief. The Swedish publisher Almqvist & Wiksell handled printing and subscriptions to the journal. Since the very beginning it was the aim of Rossby to publish in Tellus both original research articles, review articles and book reviews in all geophysical sciences. During the first 15 years almost every field in geophysics was represented in Tellus. Carl-Gustaf Rossby died in 1957 and Bert Bolin became Editor-in-Chief for the journal.

The number of submissions increased, and in 1969 Tellus became a bi-monthly journal. Since the 1960’s there was a shift of emphasis towards meteorology, atmospheric physics, atmospheric chemistry, oceanography and general fluid mechanics. The trend continued, and since the 1970’s no articles in other areas were published in Tellus.

In 1975 a new publisher, Munksgaard in Copenhagen, Denmark was contracted. Munksgaard was owned by Blackwell Publishing, which later was taken over by Wiley.

It gradually became obvious that all articles in the areas of meteorology, atmospheric chemistry, dynamic meteorology etc. were not of sufficient interest to all readers of the journal, and therefore it was decided to establish two parallel series of Tellus from 1 January 1983. These two series are: *Tellus A. Dynamic meteorology and oceanography* and *Tellus B. Atmospheric physics and atmospheric chemistry*.

The 6 annual issues increased to 10 divided into 5 issues for each series appearing alternately every month except June and December. Bert Bolin continued to serve as Editor-in-Chief for Tellus A, and Henning Rodhe became Editor-in-Chief for Tellus B.

As of 1 January 2007 the ownership of Tellus was transferred from the Swedish Geophysical Society to the International Meteorological Institute in Stockholm (IMI). The change reflected the fact that the editorial office was located at IMI and that the editors were formally employed at Stockholm University.

New techniques to process manuscripts were implemented by the publisher. In 2001 Tellus became available in electronic form, and a few years later all back volumes from 1949-2000 were also made available in electronic form. Electronic submissions of manuscripts to Tellus started in 2001.

When Bert Bolin retired in 1990 Hilding Sundqvist became Editor-in-Chief (1990-1999). After Sundqvist’s retirement Harald Lejenäs served as Editor-in-Chief 1999-2012. Today Peter Lundberg is serving as Editor-in-Chief for Tellus A.

Traditionally scientific journals have been available as paper copies or in electronic form through subscriptions handled by a publisher. During the last years Open Access publication has become common. Many organizations like research councils require that scientists they support should publish their articles in Open Access journals in order to make the results available to the scientific community free of charge. IMI decided to adopt the new way of publication, and since January 2012 Tellus is an open access journal published by the Swedish publisher Co-Action. It means that separate issues no longer are published; accepted manuscripts appear on the publisher’s web site as soon as they have been accepted for publication. Today the topics covered by the two series are:

Tellus A: Dynamic meteorology; Data assimilation and predictability; Numerical weather prediction; Climate dynamics and climate modelling; Physical oceanography

Tellus B: Air chemistry; Aerosol science and cloud physics including related radiation transfer; Surface exchange processes; Long-range and global transport; and Biogeochemical cycles of carbon and other key elements.

THE DEPARTMENT OF METEOROLOGY AT STOCKHOLM UNIVERSITY

The Department of Meteorology at Stockholm University (MISU) is the leading academic institution in meteorology in Sweden, conducting research into four main specialties: Dynamical Meteorology, Chemical Meteorology, Atmospheric Physics and Physical Oceanography. MISU also has a rich educational program, consisting of a BSc-program in Meteorology, a MSc-program in Atmospheric science, Oceanography and Climate and a PhD-program in Atmospheric science and Oceanography.

Within Stockholm University, MISU is organizationally tied to the Physics and Mathematics Section of the Faculty of Science, while the International Meteorological Institute (IMI) is an integral part of the department, but with a separate economy as an independence institute within Stockholm University, with its own budget. MISU was established in 1947, when world-renowned meteorologist Carl-Gustaf Rossby came back to Sweden after a long and very successful career in the USA. He assumed the duties of the first Chair in Meteorology in Stockholm, created for him at Stockholm's Högskola (later Stockholm University). IMI was formed some time later, by a parliamentary decision in 1955. At Rossby's untimely death in 1957, Bert Bolin took over the leadership of the department, a role that he maintained for almost three decades.

The small research group that Rossby created soon developed into a successful department with a vigorous international network. At the same time, the university structure has changed dramatically since Rossby's days, especially since the promotion reform around the turn of the century. Instead of one or a few very influential professors, holding Chairs in their subjects and leading whole departments, there are now many professors, each with his or hers individual specialties and the department leadership is a role taken on by colleagues on the principle "primus inter pares". Today, MISU is a mid-sized department at Stockholm University, with about 70 employed including more than ten permanent faculty, of which nine are professors, almost 30 graduate students, many junior scientists and a professional administration.

In 2006 the department also became a part of a virtual centre for climate research, in collaboration with three other departments at the university. This was made possible by a so-called "Linneus Grant", for the Bolin Centre for Climate Research, named on honor of Bert Bolin. The centre promotes studies of climate, climate change and variability, as well as processes of importance for the climate, and in addition to researchers from MISU involves scientists at the departments of Physical Geography (IN), Geological Sciences (IGV) and Applied Environmental Sciences (ITM). A Climate Research School is also attached to the centre. This centre cuts across several disciplines, temporal and spatial scales of climate research, and has transformed how this type of research is performed at Stockholm University. Since 2009 the centre is augmented by a strategic grant for climate modelling, and partly because of this MISU is now in a growing phase.

HEAD OF THE DEPARTMENT

Michael Tjernström, Professor of Boundary-Layer Meteorology.

INTRODUCTION

INTRODUCTION

The main goal of IMI is to promote scientific co-operation between researchers in Sweden and in other countries in the fields of meteorology and climate science. MISU researchers accordingly enjoy a high level of interaction with the international scientific community in various forms, including individual collaboration with collegues abroad, organization of international scientific meetings and workshops, involvement in large-scale international collaborative projects and participation in scientific organizations such as the World Climate Research Programme (WCRP), the World Weather Research Programme (WWRP) or the International Geosphere-Biosphere Programme (IGBP). Much of this international collaboration revolves around cross-cutting focus themes such as Arctic climate and numerical model development across a range of scales. We describe below some of the most salient examples of current international collaboration.

EC-Earth is a European project to develop and use a new Earth System model. The EC-Earth project is conducted as a European consortium of scientists from about 20 universities, research institutes and National Weather Prediction centers. KNMI, the Netherlands, ECMWF and the Rossby Centre at SMHI are leading partners. Scientists at the institute within dynamic meteorology, physical oceanography and chemical meteorology are participating in the project. EC-Earth contributed simulations to the Coupled Model Intercomparison Project Phase 5 (CMIP5), some of which were performed at MISU. The research results arising from CMIP5 were evaluated in the IPCC WG1 Fifth Assessment Report (AR5), which was presented in Stockholm in September, 2013.

Other collaboration projects in dynamic meteorology also concern model development. The GEWEX Atmospheric Boundary Layer Study (GABLS) aims at improving boundary-layer descriptions in general, and involves active collaboration with several research groups in Europe and USA. Moreover, there is long-standing collaboration with the Naval Research Laboratory on the COAMPS™ atmospheric model, and with the National Center for Atmospheric Research (NCAR), USA, on evaluating and developing the Community Earth System Model. This collaboration was also instrumental for the graduate course in climate modelling given by the Climate Research School during 2012, with international student participation.

Arctic projects cut across the various sub-disciplines at the institute. The Arctic Summer Cloud-Ocean Study (ASCOS) involves partners from many countries and is lead from MISU. ASCOS aims at understanding the formation and lifetime of Arctic summer low clouds, and started with a research expedition on the Swedish ice-breaker Oden to the central Arctic Ocean during the summer 2008, as a part of the International Polar Year. Work on evaluation the observational data collected still continues. SWERUS-C3 is a joint Swedish-Russian-US research program to investigate the climate-cryosphere-carbon interactions in the East Siberian Arctic Ocean. At the end of 2011 preparations began for an Arctic expedition with Oden which took place in the summer of 2014. Scientists at the institute from both dynamic meteorology and physical oceanography participated in the expedition. Another international Arctic project with participation from the institute is the Polar Prediction Initiative launched by the World Weather Research Programme (WWRP). It is in the preparatory phase since 2012, and planning a Year of Polar Prediction during 2017-2018.

MISU's physical oceanographers are actively engaged in international collaboration in the Baltic Way programme, aimed at improving the physical and ecological state of this inland sea. All nations bordering the Baltic Sea are represented in the program by their marine agencies and oceanographically orientated university departments. The Esonet program represents a concerted European effort to establish permanent sea-bed observatories in the Atlantic proper as well as in marginal seas for long-term monitoring purposes.

Besides a strong participation in ASCOS the Chemical Meteorology group has continued its involvement in the international Atmospheric Brown Cloud (ABC) project with focus on measurements in The Maldives and in Nepal. The main MISU/IMI contribution to ABC is to seek a better understanding of the atmospheric life cycle of soot. The group is also actively involved in examining and developing model tools for understanding aerosol-cloud interaction on a global scale (in addition to collaboration within EC-Earth community, also with UiO/MetNo using the Oslo-CAM model), and on a regional scale over the Arctic (GRACE project), Amazon (AVIAC project) and Europe (MACCII project).

The Atmospheric Physics group is involved in a number of international satellite, rocket and ground-based projects as well as modelling studies concerning the middle atmosphere. Members of the group contribute to the mission preparation of the ESA Earth Explorer Atmospheric Dynamics Mission Aeolus, to provide global line-of-sight wind profiles using a Doppler-wind lidar. The launch is expected late 2013. The group has also been deeply involved in collaboration with several international partners concerning the Odin satellite mission; launched in 2001 Odin continues to provide a wealth of atmospheric data. Beyond Odin, new middle atmosphere satellite collaborations concern ESA's plans for PREMIER, NASA's AIM satellite mission, the European ENVISAT community, and the ACE mission on the Canadian SciSat.

The Atmospheric Physics group has also continued to collaborate in international rocket programs with instruments deployed in rocket launches led by several collaborators. In 2014 the group was awarded major funding to develop a new satellite named MATS to observe the middle atmosphere. A fuller description of this project is given below.

Michael Tjernström is a member of the Science Advisory Committee of the ECMWF, vice Chair in the Atmospheric Working Group (AWG) of the International Arctic Science Committee (IASC) and member of the board for the Swedish Secretariat for Environmental Earth System Science (SSEESS). He has also been a member of the Science Steering Group of the International study of Arctic Change (ISAC). Caroline Leck is a member of Surface Ocean Lower Atmosphere Study (SOLAS) implementation committee and is the Chair of the Swedish National Committee on Geophysics (IUGG and SCOR). Gunilla Svensson is the co-chair of the GEWEX Atmospheric Boundary Layer (GABLS) and a member of the Science Steering Committee for the Global Atmospheric System Studies of which GABLS is a part. She is also a member of the Science Steering Group for the WWRP Polar Prediction Project. Annica Ekman is a member of the International Commission on Clouds and Precipitation (ICCP). Henning Rodhe has been the vice chair of the Atmospheric Brown Cloud (ABC) Science Team.

Besides the formalized collaborative projects mentioned above, scientists at the institute have also been involved in innumerable informal international projects, as can be seen from the publication list at the end of this report. IMI greatly facilitates such collaboration by its visitors program.

In the following section, a brief account is given of the activity at the four research groups at the institute, followed by two articles in which Thomas Rossby and Robert Charlton, who have been frequent IMI-guests for many years, give a personal account of what their visits have meant to them. This is followed by three articles where some of the research conducted at the institute is described in depth on a popular level. Finally, the scientific articles published by scientists at the institute since 2013 are listed.

RESEARCH ACTIVITIES

RESEARCH ACTIVITIES

This chapter contains the following subjects:

- *RESEARCH GROUPS*
- *MY LIFE ATT IMI, BY THOMAS ROSSBY*
- *THOUGHTS DURING MY 49th VISIT TO IMI, BY ROBERT J. CHARLSON*
- *MATS – A NEW SWEDISCH SATELLITE MISSION FOR MESOSPHERIC RESEARCH (JÖRG GUMBEL, LINDA MEGNER)*
- *LINKS BETWEEN LOCAL AIR POLLUTION, ATMOSPHERIC CIRCULATION AND GLOBAL CLIMATE (ANNICA EKMAN)*
- *JET STREAM VARIABILITY AND CLIMATE (A. HANNACHI AND L. CHAFIK)*
- *LIST OF PUBLICATIONS*

RESEARCH GROUPS

ATMOSPHERIC PHYSICS

The Atmospheric Physics group (AP) at MISU/IMI runs a research programme on the aeronomy of the middle atmosphere. Focussing on the altitude range 10-100 km, the field of research of our Atmospheric Physics group concerns in particular radiative and chemical interactions of aerosols and trace gases as well as dynamical and chemical coupling between different regions of the atmosphere. In the middle atmosphere, aerosol particles of interest include ice clouds, particles of meteoric origin, and the background aerosol formed by conversion from various gases.

Our research programme in this field includes a wide range of experimental and theoretical techniques. The experimental component aims at the development, improvement and application of measuring techniques for in-situ and remote sensing studies. Spectroscopic techniques and particle microphysics are examples of particular competence. Central experimental activities are connected to the Swedish Odin satellite as well as the use of Esrange Space Centre in Northern Sweden by means of sounding rocket launches and lidar operations. Complementary model studies are essential to put our experimental results in a larger perspective of understanding the middle atmosphere. Ongoing model studies range from the microphysics of particle formation to global dynamics.

The long-term goals for our atmospheric physics programme at IMI/MISU are:

- to establish the distribution and properties of important trace gases, aerosols and clouds in the middle atmosphere,
- to understand underlying transport processes and the dynamical coupling between various parts of the atmosphere,
- to obtain a better understanding of the microphysical, radiative, and chemical interactions that determine the properties and variability of trace gases, aerosols, and clouds.

CHEMICAL METEOROLOGY

The research in chemical meteorology (CM) involves studies of the occurrence and transformation of chemical constituents in the atmosphere as dependent on homogenous and heteorogenous chemical reactions and meteorological conditions: winds, clouds, precipitation etc. Several of the research projects are motivated by the concern about the effects of anthropogenic changes in the chemical composition of the atmosphere: impact on climate, ecosystems - including acidification – and human health.

Studies of the occurrence of aerosol particles and gaseous constituents of importance for cloud formation, biogeochemical cycles and climate play a central role in the research activities. The research is carried out as part of comprehensive international field campaigns measuring both in-situ and by remote sensing. The field-work is complemented by laboratory studies and theoretical modelling of different complexity to examine how different chemical constituents interact with atmospheric mixing and transport. The models are used to interpret both the in-situ and remote sensing collected data and to study the impact of long-term past and future changes in atmospheric composition.

The CM group at MISU/IMI is involved in the ABC-project (www-abc-asia.ucsd.edu/) and the ARDEX project, which both aim at a better understanding of the atmospheric life cycle of soot and its climate effects over the Indian sub-continent and the surrounding oceans. ASCOS (www.ascos.se) and GRACE (http://www.itm.su.se/page.php?pid=680), are two efforts that are focused on high-latitude atmospheric sources of aerosol particles and their role in cloud formation and Arctic climate change. The project AVIAC (http://www.itm.su.se/page.php?pid=658) attempts to study the interaction between aerosol particles and clouds over the Amazon, and AFaCC (http://www.itm.su.se/page.php?pid=803) aimes at studying the interaction between aerosol particles and convective clouds.

The CM group is also a partner in developing the description of aerosol particles and their influence on clouds and climate in different global climate models, including CAM-Oslo and EC-Earth (www.ecearth.knmi.nl). We also perform molecular dynamic simulations in collaboration with partners at the Swedish Royal Institute of Technology and host a newly developed large-eddy simulation model for detailed studies of aerosol-cloud interaction.

DYNAMIC METEOROLOGY

Research in the area of dynamics covers processes from the global scale down the turbulent scales. The large scales concern the general circulation of today, the past and the future. Many of the studies of present climate are based on so-called reanalysis products, i.e. global gridded fields of all relevant meteorological variables with a typical time resolution of hours, available from international weather prediction centers. These fields are constructed using a Numerical Weather Prediction (NWP) model with all available observations assimilated. Examples of studies are analyses of the Hadley circulation, of the position and variability of the Atlantic jet stream, of the occurrence of coastal low-level jets, and of the general characteristics of the storm tracks, including the preferred dynamical setting for extreme storms that take landfall in Europe to develop.

Small-scale dynamic motions, smaller than the computational grid in a climate or NWP model, are boundary layer and mesoscale processes. The latter can be resolved in high-resolution models, but the boundary layer, which is dominated by small scale turbulent motions, is not directly resolved for atmospheric conditions. Research in this field is motivated by the effect those motions have on the larger scale, and by the need to skillfully implement these effects in larger-scale numerical models for weather and climate. Regional studies include monsoon circulation and coastal flows. Paleoclimate studies concern deep-time climate *change as* well as the more recent Holocene climate. Much of the science is done in collaboration with national and international collaborators.

A common denominator for many of the studies in dynamic meteorology is the use of numerical models. They are frequently used, mostly in combination with observational data, in many different ways to study fundamental aspects of the dynamics as well as the interaction between different scales. These models range from simplified models of the atmosphere to global and regional NWP models, Single Column Models (SCM), Large Eddy Simulation (LES) and regional and global climate models (discussed in a separated chapter). Simplified models are used to investigate the impact of organization on the large-scale circulation of convective clouds that are of smaller size than the computational grid of a NWP model.

PHYSICAL OCEANOGRAPHY

A large part of the research in the physical oceanography (OC) group at MISU/IMI uses numerical models, but observational work (primarily using satellite altimetry) and theoretical work is also done. Some of it is global, and some is regional with an emphasis on the Baltic Sea and the Nordic Seas. Our main tool for global modelling is the NEMO model, which is also the ocean component of EC-Earth, a joint European coupled climate model. We have also participated in the development and the evaluation of NEMO.

The OC group has been very active in developing new diagnostic tools for analysing the global overturning circulation. The traditional way to do this is to compute the overturning stream function in depth-latitude coordinates; density-latitude coordinates are also often used. New methods recently developed at MISU/IMI include using depth-density coordinates, which provides a transparent picture of the energetics of the overturning, and temperature-salinity coordinates, which displays the water-mass transformation and provides a link with the traditional observational oceanography. Related subjects that have been studied with global models are the vertical and latitudinal transport of heat and freshwater.

We have earlier developed a practical way of computing the energy of the internal waves that are excited by tidal currents over rough bottom topography. The deep overturning circulation is largely driven by the vertical mixing caused by breaking internal waves. This method has now been used for various applications, such as the parameterization of the bottom drag in tidal models and the interpretation of sediment transport data.

Some of our regional modelling work concerns the Arctic Ocean; both its modern circulation (in collaboration with SMHI) and its paleo-circulation (in collaboration with the Department of Geological Sciences). The Baltic Sea is studied in collaboration with SMHI, using general circulation models. These are used both for physical oceanographic applications and for biogeochemical studies, for example studies of the transport of larvae. The transport predictions of the models have also been validated by experimental studies with surface drifters.

MY LIFE AT IMI

Thomas Rossby

My father moved his American family to Sweden in 1947, so from the age of 10 I grew up in an American-speaking household, but spoke Swedish in school, with friends, around town, and especially at boarding school in Sigtuna where I took studenten. Immediately following my civilingenjör degree at KTH I moved to the U.S. to see what life was like there since until then I knew little about living and working in the country I had started my life in. My Swedish bride-to-be, Birgitta Ribbing, liked the idea too so we moved there in 1962. I had in mind to become an engineer in electronics, but my mother, sister and friends urged me to go to graduate school instead. So somewhat reluctantly I applied to MIT and soon found myself busy designing an experimental study of Benard convection subject to rotation! My guess is George Veronis and Willem Malkus persuaded my advisor Raymond Hide to suggest this as a possible research topic. I really enjoyed developing the equipment and conducting the research. After MIT I resumed my engineering interests and worked with Doug Webb, an incredibly talented electro-mechanical engineer, to develop the SOFAR float concept. Soon after came other instruments that would evolve into widely used tools in oceanography. So starting in the late 60s at Yale University most of my work centered on using subsurface neutrally buoyant floats to explore the meso- and large-scale ocean circulation from a Lagrangian point of view. This was very exciting stuff. In 1975 I moved to the University of Rhode Island and quickly found myself running a large research program, advising students, and teaching physical and dynamical oceanography. But my dream of a career in electronics was not totally lost thanks to the development work I did with Jim Fontaine, particularly with the evolution of the RAFOS float technology. So I became firmly involved with all things academic – including working with some fantastic students - here at the Graduate School of Oceanography; my sons were growing up and eventually going to college here. Sweden seemed increasingly far away.

Some 30 years after I left Sweden, I was asked to serve as the U.S. representative on the ICES Working Group on Oceanic Hydrography (WGOH). It was at my first meeting in Bergen in April 1994 that I met another committee member, Peter Lundberg. He asked if I might be interested visiting IMI and MISU. Little did I realize what a big moment this was to be! I arrived at IMI in October 1995 for the start of a whole new career or venture I am strongly tempted to say. During that first visit I ran some numerical simulations (published in Tellus) of the thermal convection experiment I had conducted during a summer break in 1963 at Henry Stommel's initiative. It would never have occurred to me to do this had I stayed in Rhode Island attending to project matters and supervising student research. But just as important, the combination of WGOH and IMI proved to be the start of a wonderful new initiative, namely to measure currents between Scotland and Greenland from the Royal Arctic Lines container vessel Nuka Arctica. Thanks to some start-up funds from my Dean Margaret Leinen, the long-term loan of the acoustic Doppler current profiler (ADCP) from Bogi Hansen in the Faroes, technical support from Martin Mork at the University of Bergen, and a grant to IMI from the Wallenberg Foundation for the crucial Ashtech GPS compass, we instrumented the ship and gradually built up a 4-year database of accurately measured currents between Scotland to Cape Farewell (and up the west Greenland coast). These data were recently used in Leon Chafik's PhD thesis and published in JGR earlier this year. I should add that a deeper reaching ADCP was installed on the Nuka Arctica in Fall 2012 and a new valuable database 10 years later is beginning to take shape.

Building on the Nuka Arctica success, the ICES WGOH encouraged the start of another ADCP line, this time on the ferry Norröna that operates out of the Faroes to Denmark and Iceland thus traversing almost all warm water flowing into the Nordic Seas. The project started in earnest in 2009 and thanks to these measurements we have found that a significantly greater fraction of warm water flows into the southern Norwegian Sea between Iceland and the Faroes, and less between the Faroes and Scotland than previously thought. I mention these activities for several reasons.

First, the Nuka Arctica and Norröna programs would never have come about had I not met Peter Lundberg! Second, this method of measuring ocean currents is proving to be far more effective than we first realized. Oceanographers use hydrography and altimetry (sea level tilt) to estimate transports using the dynamic method (geostrophy). This works quite well, but has some well-known shortcomings. The ADCP changes all this: we now measure currents and transports and we do so accurately. But due to eddy activity in the ocean we need to repeat these measurements many times to resolve the underlying mean circulation. Experience has shown that by working with the merchant marine this can be done very effectively – and vessel operators have been more than willing to help! The Nuka Arctica and Norröna programs (and another on a vessel operating between New Jersey and Bermuda) led to a proposal to SCOR/IAPSO to set up a working group to develop a framework for working with merchant marine on a systematic basis. The proposal was funded and the group prepared a report 'OceanScope' parts of which was drafted during visits to IMI in 2010 and 2011, and released in early 2012. Although the report has been well received it has thus far had little impact. Nonetheless, I really think there are some tremendous opportunities for improved (accurate and detailed) study of the ocean this way so I am hopeful that we will see the ADCP and other instruments installed on more vessels before long!

I left Stockholm in 1962, and while Birgitta and I kept close contact with family and relatives that was about it. So coming to IMI has been absolutely fantastic both professionally and personally. I have worked on a number of projects that would never have seen the light of day had IMI not entered my life, so to say. In addition to the above, there is the paper with Johan Nilsson about how the Gulf Stream might be responsible for the rapid warming at the end of the last glacial period. I still think the idea has merit, but I haven't a clue how to test it. Another outcome of working with the WGOH and IMI is the study with Vladimir Ozhigin of Nordic Seas hydrography from an isopycnal point of view. We show how wintertime convection mixes down salt leading to increased spiciness at depth. This gives us another signature of where and to what isopycnal surface waters can be injected in winter. Last spring I used Argo data to study the origin and fate of thin lenses in the southeast Pacific. This – totally serendipitous – study would never have been completed had I stayed at home! While IMI has not put any demands on my time, it has always been a pleasure to give a short 'laboratory' course in physical oceanography to the graduate students. It is kind of a vicarious way of going to sea: bringing real data into the lab.

These visits have not only been enormously rewarding scientifically, they have become a homecoming of sorts, a way of rejoining the world I grew up in and to which I owe so much. A delightful consequence of these visits is that IMI has placed me in different locations each time I come! Starting at Lappkärrsberget the first year, I have now lived in all parts of innerstan including Gamla stan and Bromma/Nockeby. First prize has to be living at Mariatorget even though most of the other apartments are very close runner-ups.

In brief, I am enormously grateful to Peter Lundberg and IMI for opening up a whole new adventure in my life, professionally and personally. Working with colleagues and students at IMI has been most rewarding, and now the honorary doctorate degree, I thank you so much! Hopefully these notes will give you an idea of how deeply indebted I am to you all.

THOUGHTS DURING MY 49TH VISIT TO IMI

Robert J. Charlson

This year is the 50th anniversary of first meeting the late Georg Witt at a meeting re. noctilucent clouds (NLC) held in London at the Royal Society in November of 1964. When I think back about the many wonderful visits that I/we have enjoyed at MISU/IMI over almost a half century, it becomes an obvious and formative aspect of my entire career as a scientist. I will try to recall a few highlights of my experience made possible by IMI. Meeting Georg Witt sets the tone for the entire recollection.

The year was 1964, and I was in residence at the Cloud Physics Department at Imperial College (IC) in London. I heard of a symposium to be held at the Royal Society and that the famous researcher on noctilucent clouds, Georg Witt, would be there. I managed to get myself invited and then met Georg, who had exactly the same equations as did I for explaining the occurrence of NLC. I felt totally defeated, knowing that Witt must be of a mind to publish these very soon. Little did I know of Georg's habits re. publication. And, as it happened, Prof. Mason who led the Department of Cloud Physics asked me the next day to take Georg shopping at Liberty's Department Store for toys for Georg's child, Susanna. Even though I felt quite intimidated by Georg's status, I went to the toy shop and found Georg to be a very helpful and communicative person. Our non-stop discussion led Georg to invite me to visit MISU/IMI as soon as possible to plan together what research we thought should be done. Needless to say, I was both overjoyed at the invitation and relieved that Georg's competitive edge seemed to have vanished. So, at the Christmas break at IC in December 1964, my wife, Pat, and I (who I had married earlier that year) took off by train from London, bound for Scandinavia. That trip via Copenhagen, Oslo and Stockholm brought us to MISU/IMI, at that time over on Tulegatan. The discussions that day with Georg led to a dinner in the evening at their apartment in Kalhäll where Georg and Lena (who had just given birth to their second daughter, Magdalena) served a fine dinner after which Georg took us back to the earliest version of the pendeltåg (with a steam locomotive, no less), with Pat riding in a sparkstötting. Georg's instructions were clear: We were to visit northern Sweden in the summer 0f 1965 so that we could together view the NLC.

That summer did work out eventually, and Pat and I drove a Volkswagen up to Sweden in a big hurry, owing to last minute planning, and indeed I was rewarded with about a 15 minute glimpse of the fabled NLC. By then, we were totally out of money, and I had to approach Georg with a plea for help. He said, don't worry, Bert Bolin will take care of you. And he did. A check from IMI arrived shortly thereafter, and it was cashed at the Post Office/Bank in Ostersund. Thus began a lifelong experience, at first quite totally focussed on Georg Witt's activities and then more broadly with many of the scientists at MISU/IMI. Importantly, while staring at stratus clouds (the plague of Torsta, Georg called them) in the summer of 1965, Georg had described the light scattering theory of Gustav Mie in non-mathematical terms to suit my chemist's mind. Little did we know at the time that I would go on to study light scattering by atmospheric aerosol. Develop an instrument (the integrating nephelometer) for measuring the optical extinction by tropospheric aerosols and then go on from that to investigate the chemical nature of light scattering aerosols in industrial regions. Sulphate compounds deriving from the oxidation of sulfur dioxide became a main focal point. After publishing a (very premature) paper on the subject with Bert Bolin in 1976, it took one and a half decades before I published with Joakim Langner and Henning Rodhe (both of MISU/IMI) a calculation of the amount of solar radiation reflected by those same particles. I.e., we had, for the first time ever, calculated the global effect and the geographical map of climate forcing by anthropogenic sulfate aerosols. Needless to say, that paper, published in Tellus in 1991, has stood as a reference against which newer papers are measured.

Along the way, beginning in the 1970's, my relationship with Henning Rodhe began to develop and, among other things, we invited him to be the author of a chapter in a textbook on biogeochemcal cycles. I should mention that Henning Rodhe and I also published in 1981, in the journal "Nature", a very important paper on the role of the natural sulphur cycle on rainwater acidity; to date, it is the only paper that either Henning or I ever published where the publisher merely sent the page proofs and said that there were no suggested changes by the referees. Wow!

While all this was going on (1965-1998), I had an adequately fulfilling and productive career as a professor at the University of Washington in Seattle; however, the politics there were hit-and-miss and by the mid 1990's it had became impossible in my view to continue to try to develop interdisciplinary Earth sciences as an academic subject. After an ill-fated meeting with the Deans of several of the relevant colleges, I gave up and (with Pat's help) decided to retire from the University of Washington. That decision was effective on July 1 of 1998, and I began to wind down after an arduous few decades at Washington. Then, just about six months after formal retirement from the University of Washington, I received a letter from HM King Carl XVI Gustav of Sweden, asking whether I would accept a position as the "King Carl XVI Gustaf Professor of Environmental Science, 1999-2000. It took no time at all to reply "yes", and a whole new career blossomed from that moment on. Yes, we were in residence once again at MISU/IMI for the academic year 1999-2000. We also had a very nice sailboat built on the west coast of Sweden and spent the summer of 2000 cruising in it in Sweden and Finland.

There are stories galore about the 49 individual visits that have happened over the 50 years from 1964 until now, but there is not enough room to tell them all. It suffices to say that the whole affair started with an intellectual provocation re. an esoteric sort of atmospheric phenomenon; it continued with a sigificant expansion of the number of people involved, and is an historic success story if measured in terms of scientific productivity. Along the way, I met many new people and developed strong working relationships with many of them. Post-docs came to Seattle and ended up on the faculty at Stockholm University (e.g., H.C. Hansson). A couple of my graduate students in Seattle ended up on the staff in Stockholm (e.g., Kevin Noone and John Ogren). And the story goes on. During the present visit in October of 2014, I have been given the pleasant task of helping to finish two scientific papers, coauthored by Anders Engström and Frida Bender. And, it is worth noting that Anders Engström, who is doing research at MISU, was a post doc in Seattle in 2013 and 2014.

All of this has been enabled by the International Meteorological Institute in Stockholm, and the successes that this chronicle represents attest to the importance of IMI in the past, now and on into the future

MATS - A NEW SWEDISH SATELLITE MISSION FOR MESOSPHERIC RESEARCH

Jörg Gumbel, Linda Megner

The Professor emeritus Georg Witt passed away in July 2014 at the age of 83. After he came to institute in 1954, he built up the research activities that have been the basis for MISU/IMI's Atmospheric Physics programme ever since. The focus of this programme is on the Earth's mesosphere and lower thermosphere (MLT), i.e. the atmospheric altitude range between about 50 and 150 km. In many regards, this altitude range is a transition region between the lower altitudes that are our direct atmospheric environment and the higher altitudes that are our space environment. Being such a transition region, the MLT is host for a variety of interactions and phenomena. One of these phenomena is noctilucent clouds (NLC) that caught Georg's attention already in the 1950s. He then started a ground-based observation programme for these highest clouds in the atmosphere at altitudes around 80-85 km (figure 1). It is fascinating to note that the stereoscopic techniques used by Georg 60 years ago are a direct predecessor of the tomographic satellite measurements that we are planning now. These ground-based studies were soon to be followed by rocket-borne in-situ measurements. This made Georg one of the pioneers of Swedish space research in the 1960s. The cloud studies were to be complemented by other sounding rocket programmes in the 1970s and 1980s, addressing the physics, chemistry and dynamics of the MLT. Georg would call it "Physistry" as he did not see much sense in dividing atmospheric science into separate sub-disciplines. A particular focus would be on the excited atomic and molecular states in this part of the atmosphere. These give rise to a wealth of optical emissions observable as airglow. All this activities became the foundation for the Atmospheric Physics group's growing experience in optical measurement techniques. These experimental efforts did not stay limited to ground-based and in-situ measurements, but would include a strong interest in space-borne remote sensing starting in the 1990s. This concerns in particular the Swedish-led Odin satellite that Georg helped to establish as a highly successful collaboration between atmospheric scientists and astronomers.

Figure 1: Stereoscopic picture of NLC resulting from Georg Witt's ground-based observations at Torsta (63°N, 15°E), Sweden, in 1958. The photographic pair printed together was taken with two cameras at a distance of 51.5 km. The picture can be viewed through couloured 3-D glasses (blue filter over the right eye, red filter over the left eye). Structures in the clouds are caused by gravity waves and Kelvin Helmholtz instabilities. For details, see the original publication by G. Witt, "Height, structure and displacements of noctilucent clouds", *Tellus*, 14, 1-18, 1962.

For Georg, life was about communication. He would often talk to us about what he considered most important in atmospheric research. Some points would always be at the heart of his sermon: the understanding of NLCs, the understanding of airglow, the three-dimensional view of the atmosphere, and the use of modern optical techniques. Over the last three years, a new Swedish satellite mission has been conceived. Its name is MATS, and in many ways it is a quintessence of Georg's message to us. MATS aims at exciting new ways of studying atmospheric structures, NLCs and airglow by optical methods. The acronym MATS stands for "Mesospheric Airglow/Aerosol Tomography and Spectroscopy". Georg will not be there to see MATS fly. But he was with us when MATS got selected by the Swedish National Space Board, and it sure made him happy.

Scientific background

What is behind the five words that make up the acronym MATS? From its orbit about 600 km above the Earth's surface, MATS will use optical measurement techniques to study the mesosphere. It does so by making use of optical phenomena that are specific for the mesosphere. One such phenomenon is light emitted from oxygen molecules, a process called airglow. Another such phenomenon is light scattered by aerosol particles in the form of noctilucent clouds. In order to gain information about atmospheric structures and wave patterns from these phenomena, MATS will apply tomography: by looking at the mesosphere from many different directions it will allow us possible to reconstruct a three-dimensional picture. Even more information can be obtained by combining tomography with spectroscopy: by analyzing the detected light at different wavelengths it will become possible to draw conclusions e.g. about atmospheric temperatures, composition or cloud properties. By collecting data from the mesosphere during two years time in orbit, MATS will thus allow us to address a wide range of scientific questions about this remote part of the atmosphere.

As a transition region, the Earth's mesosphere and lower thermosphere are strongly connected to altitudes below and above. Despite this fact, this region has frequently been treated as a dividing line for atmospheric research. Traditional circulation models for the lower and middle atmosphere have the MLT region as their upper boundary, while thermospheric and ionospheric models have this region as their lower boundary. Only recently a broad interest has developed in "whole atmosphere" approaches that try to overcome this division.

As for the middle atmosphere (below ~100 km), wave dynamics ranging from small-scale gravity waves to large scale planetary waves provide strong coupling mechanisms between different regions of the Earth's atmosphere. This is particularly evident at altitudes around 70-120 km where upward propagating disturbances reach their maximum amplitudes and break, thus depositing momentum and energy onto the large-scale flow, and driving a global mesospheric circulation that is far from radiative equilibrium. A prominent manifestation of this is the occurrence of noctilucent clouds in the extremely cold polar summer MLT.

As for the upper atmosphere (above ~100 km), the MLT region is an important driver in terms of wave input. Over the last decade, a broad research field has emerged with focus on this upward coupling. In addition to model efforts, there has been growing observational evidence of thermospheric and ionospheric responses to dynamical processes in the lower and middle atmosphere. This includes the role of gravity waves, tides and planeraty waves on ionospheric morphology. Also effects of sudden stratospheric warmings have been traced in the thermosphere and ionosphere. It has been estimated that more than half of regular daily and seasonal variability in the thermosphere and ionosphere is forced from below.

In order to study these interactions, there is substantial need for more data in the MLT region. As compared to the data-rich lower atmosphere and upper thermosphere, global data on the dynamics and variability of the MLT transition region are frequently pointed out as limiting factors for future scientific progress. A central idea of MATS is to analyse structures in the MLT over a wide range of spatial and temporal scales. The primary goal of MATS can thus be summarized as

How are planetary waves and gravity waves of different horizontal scales globally distributed in the MLT?

Over a period of two years, MATS will build up geographical and seasonal climatologies of mesospheric wave activity. This database will be the starting point for scientific analysis in various directions. Central scientific efforts are distributed according to the following overlapping subject areas:

• Local wave properties: How do wave interactions at different scales influence local wave spectra? What are the overall ratio and the time-lagged correlation of the different wave activities?

• Connections to below: How does MLT wave activity relate to planetary wave structures in the lower atmosphere? How does MLT wave activity relate to source regions of gravity waves in the lower atmosphere? What is the relative role of waves propagating from below and instabilities generated locally in creating local structures in the mesosphere?

• Connections to above: How does MLT wave activity correlate with transient processes in the thermosphere and the ionosphere? How can mapping of mesospheric wave activity be applied as an input to studies of thermospheric variability?

• State of the mesosphere: How does the temporal evolution of gravity wave spectra relate to the temporal evolution of the mean temperature on time scales of days to weeks? How does spatial and temporal variability due to waves affect observational studies of long-term trends in the mesosphere?

• Mesospheric clouds: How does wave activity control the topology of ice layers (noctilucent clouds) in the polar summer mesosphere? How do small-scale vertical/horizontal structures affect ice microphysics and, thus, the spatial and temporal variability of cloud particle populations? How do local cloud structures affect different NLC remote sensing techniques and conclusions drawn from these techniques?

• Atmospheric models: How can we use MATS wave data to constrain current General Circulation Models and Climate Models? How can gravity wave parameterization be improved to reduce large uncertainties in current descriptions of wave sources, wave propagation and wave interactions?

Satellite Concept

The current MATS satellite concept has been proposed in response to a Call for Ideas on "Innovative low-cost research satellite missions" issued by the Swedish National Space Board in 2011. However, orginal ideas for a MATS satellite were developed by Jacek Stegman and Donal Murtagh at MISU already in the 1990s. The pioneering work in the 1960s and 1970s became a foundation for today's remote sensing. In the early years, research focus was on understanding the basic physics behind phenomena like NLC or airglow. Once this physical understanding had been established, these phenomena could undergo a transition from being objects of research to being tools of research. Hence, building on the work by Georg Witt and many others, today we use NLC or airglow as convenient observational tools for global studies of atmospheric dynamics, physics and chemistry.

Space-borne limb imaging in combination with tomography and spectroscopy opens exciting new ways of probing atmospheric structures. MATS applies these ideas to the mesosphere. As described above, its science questions focus in particular on mesospheric wave activity and noctilucent clouds. Primary measurement targets are airglow in the so called O_2 Atmospheric band in the near infrared (wavelengths 759-767 nm) and sunlight scattered from noctilucent clouds in the ultraviolet (wavelengths 270-300 nm). While tomography provides horizontally and vertically resolved data, spectroscopy allows analysis in terms of mesospheric composition, temperature and cloud properties.

Limb-looking instruments onboard MATS will image the atmosphere along the Earth's tangent direction. A major innovation on atmospheric structure retrieval is the application of tomographic inversion techniques. MATS' tomographic and spectroscopic retrievals are based on a co-analysis of data from six spectral channels in the infrared and ultraviolet. Fields of view are up about 50 km in the vertical and 250 km across track. The image detection is based on advanced CCD sensors with readout electronics that allows for flexible image processing. A critical challenge for the limb instruments is stray light suppression, requiring a careful design of optics, baffles and instrument interior.

In addition to these MATS limb measurements, a nadir imager will take pictures of O_2 atmospheric band emissions from below the satellite. This provides complementary information on smaller spatial scales, albeit restricted to a single spectral channel. Because of the susceptibility of nadir measurements the lower atmospheric background light, these data will be restricted to the nighttime.

The MATS concept has been developed in collaboration between several Swedish research groups and space industry. Behind the proposed MATS instrumentation is a consortium comprising

• the Department of Meteorology (MISU/IMI), Stockholm University

• the Department of Earth and Space Sciences, Chalmers University of Technology, Göteborg,

• the School of Electrical Engineering, Royal Institute of Technology (KTH), Stockholm,

• Omnisys Instruments, Göteborg/Stockholm.

This instrument consortium shares the responsibiluty for designing, building, varifying and calibrating the optical instruments onboard MATS. In parallel, tomographic inversion algorithms and scientific analysis tools are being developed. Beyond this concortium, a MATS Science Team is being formed that consists of Swedish and international researchers contributing in different ways to the mission and science development.

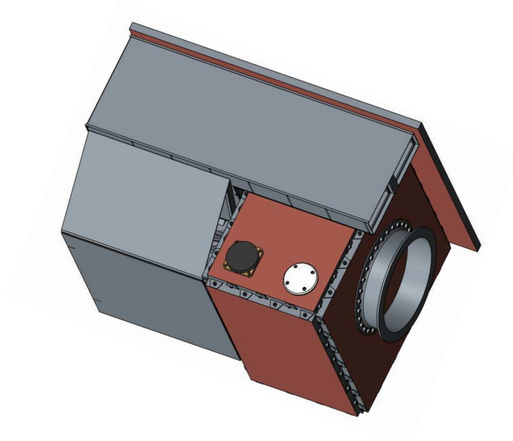


Figure 2: Preliminary layout of the InnoSat/MATS satellite. Red structures mark the InnoSat platform, while grey structures show part of the MATS payload with the optical instruments.

The above activities concerning instruments and science are complemented by a platform consortium comprising OHB Sweden in Stockholm and ÅAC Microtec in Uppsala. This consortium takes care of developing a new satellite platform called InnoSat. The InnoSat spacecraft is a versatile platform intended for a whole range of future scientific missions. It has been designed to utilize a small launcher volume so that it can be launched "piggyback" on a rocket together with larger satellites. MATS will be the first scientific payload to be flown on InnoSat. It is being prepared for a launch in 2018.

Science and heritage

Based on a two year mission, MATS the scientific analysis will address atmospheric structure and variability, wave interactions, and NLC microphysics. We have been in the fortunate situation to be able to test both analysis methods and scientific ideas long before the planned launch. In particular, MATS builds on the heritage from the Odin satellite mission. Extensive pre-studies of the tomographic and spectroscopic methods have been performed with the Optical Spectrograph and InfraRed Imager System (OSIRIS) onboard Odin. To this end Odin was re-programmed to operated in specific “tomography” modes of limb scanning.

.

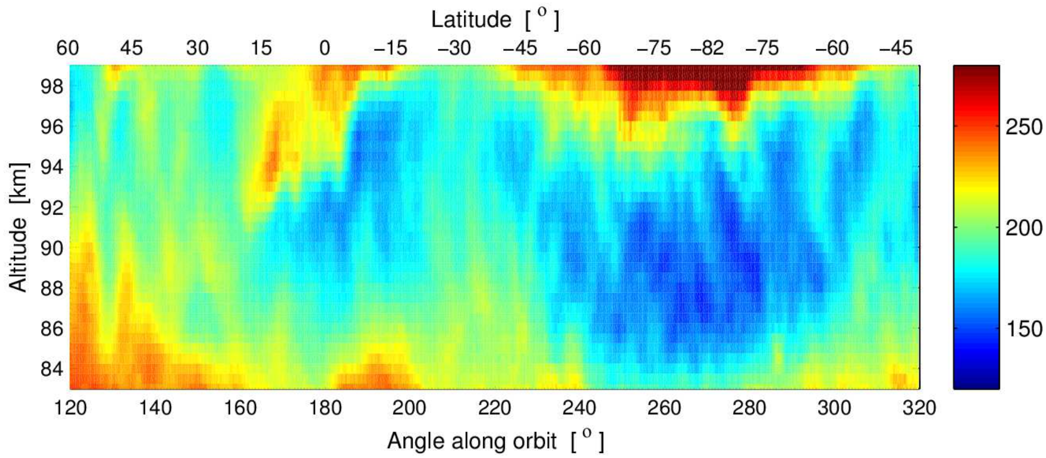


Figure 3. Temperature retrievals from the O_2 Atmospheric Band based on tomographic scans with the Odin/OSIRIS. Temperatures [K] are shown from the daytime part of Odin orbit 63973 on November 13, 2012. As a test of the MATS tomographic measurement concept, Odin was operated to perform short limb scans covering tangent altitudes of 82-102 km.

Figure 3 shows an example of OSIRIS tomographic retrievals of temperatures from the O2 atmospheric band airglow. Similar to the planned MATS analysis, spectral radiances in four wavelength channels were run through a tomographic inversion in order to produce local volume emission rates. Spectral temperature analysis was then applied in order to retrieve local temperature information. The example in Figure 3 shows expected global features like the cold polar summer mesopause at altitudes around 89 km, but it also reveals substantial horizontal and vertical (wave) structures in the temperature field. Note that the limb-imaging capabilities of MATS will provide atmospheric structures with significantly better horizontal resolution than the limb-scanning observations by Odin.

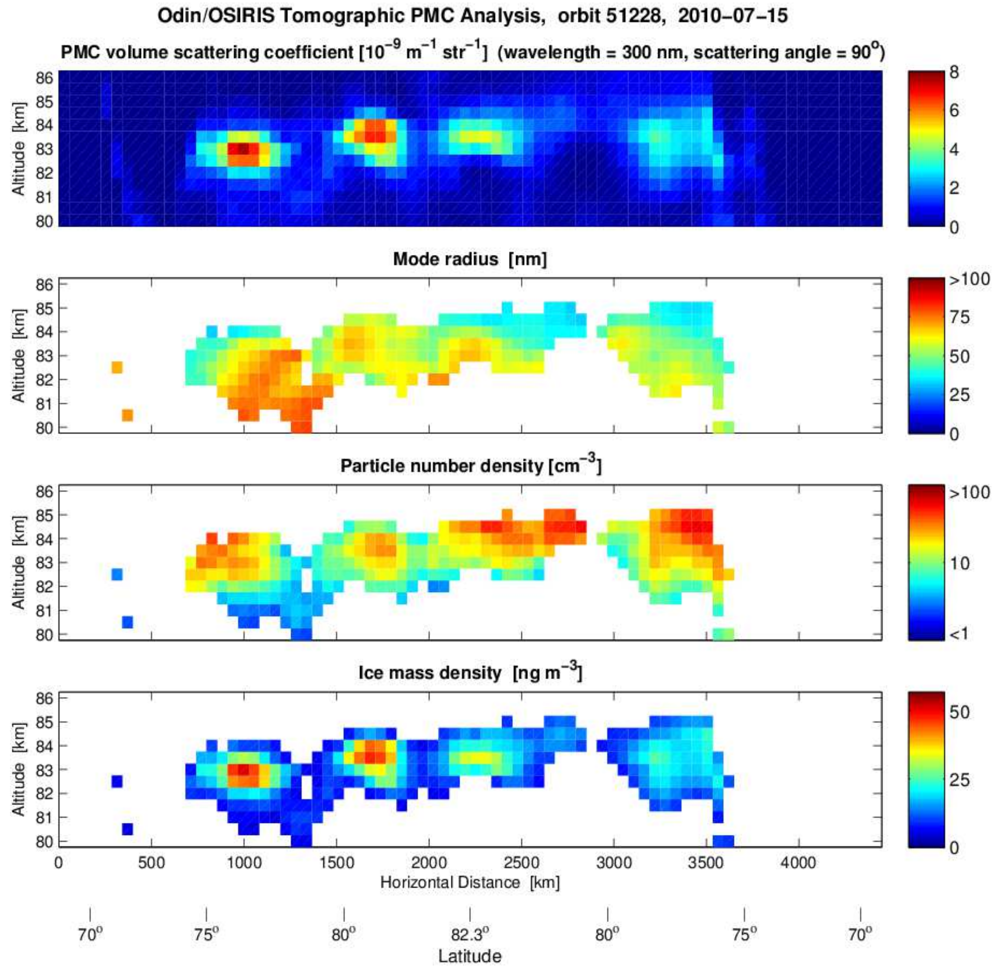


Figure 4. Example of noctilucent cloud retrievals from Odin/OSIRIS based on tomography and spectral analysis. The upper panel shows the volume scattering coefficient as primary product of the tomographic algorithm. The lower three panels show NLC particle size, number density and ice content as a result of applying spectroscopic analysis to the tomography results. For these tomographic NLC retrievals, Odin was operated to perform short limb scans covering tangent altitudes 73-88 km Note that these OSIRIS results are based on limb-scanning. The limb-imaging capabilities of MATS will further improve the horizontal resolution of these images

NLCs are measured at two wavelengths. One channel is sufficient to analyse (wave) structures in the NLC brightness. By using two channels, spectroscopic analysis can provide additional information about particle microphysics (particle sizes, number density, ice mass). Again, this can be illustrated with tomographic test runs performed with Odin/OSIRIS. Figure 4 shows tomographically retrieved local NLC scattering coefficients (upper panel). With these tomographic results at several wavelengths as input, spectroscopic analysis reveals NLC particle sizes, particle number densities, and ice concentrations (lower panels).

More examples of scientific results that could be obtained from the tomographic and spectroscopic analysis of Odin/OSIRIS data are discussed in a recent paper by K. Hultgren and J. Gumbel ("Tomographic and spectral views on the lifecycle of polar mesospheric clouds from Odin/OSIRIS", Journal of Geophysical Research, 119, 14,129-14,143, doi:10.1002/2014JD022435, 2014.) More about Georg Witt and the history of Atmospheric Physics at MISU/IMI can be found in a memorial article in the Journal of Atmospheric and Solar.

LINKS BETWEEN LOCAL AIR POLLUTION, ATMOSPHERIC CIRCULATION AND GLOBAL CLIMATE

Annica Ekman

Air pollution is a problem that has been following humankind since prehistoric times. Aerosol particles, emitted from fires, coal burning and other industrial activities are particularly problematic as they strongly affect human health (cf. Figure 1). In addition, the particles have other negative impacts on society, e.g. on aviation safety through reduced visibility and on building materials through acid deposition. Aerosol particles also have a climate effect by influencing the amount of solar radiation reaching the surface, either directly by reflecting or absorbing of sunlight or indirectly by modifying cloud properties. When increasing or reducing the concentration of aerosol particles in the air, the amount of energy reaching the surface is changed. This change can influence climate locally, but also globally by altering regional and global circulation patterns, and consequently other factors such as cloud cover and heat transport. At MISU, there is ongoing research trying to understand the links between local changes in aerosol particle emissions, atmospheric circulation and global climate

Figure 1.Severe pollution (smog) in Beijing, China

This resolution is coarse relative to the scale of many motions in the atmosphere, for example synoptic scale frontal systems and other important physical processes such as clouds and their interaction with radiation. The effect of those motions and processes must be allowed to affect the motions on the larger scales, and this is done by parameterizations. These are built on advanced knowledge of the behavior of the small-scale processes gained from theory or fine-scale models but are also heavily dependent on observational data. Such parameterizations introduce uncertainty in the GCM-based simulations of future climate.

Changes in aerosol particle emissions over time

Aerosol particles contain different chemical constituents and may be emitted both from natural and anthropogenic sources. Human activity contributes to the emission of a large number of particles, mainly consisting of sulfate, soot (black carbon) and organic matter. While soot absorbs sunlight, sulfate and organic matter reflect solar radiation, and together with the effect of aerosol particles on cloud reflectivity, increased aerosol concentrations in the atmosphere will on average cool the planet. Fig. 2 shows the estimated trends in emissions of sulfur dioxide, a precursor of aerosol sulfate, from 1850 until 2005. As industrialization took place in Europe and North America at the beginning of the 20th century, sulfur emissions increased dramatically but started to decline in the 1970's. Emissions from coal burning in the former Soviet Union peaked around 1990. Sulfur emissions in Asia have increased steadily since the 1950's, but are projected to start decreasing during the beginning of the 21st century. The drastic changes over time in the spatial distribution and magnitude of aerosol particle emissions should have consequences for the local radiation balance. The question is if and how these local radiation changes also induce changes in the large-scale circulation, and how this affects the distribution of the surface temperature.

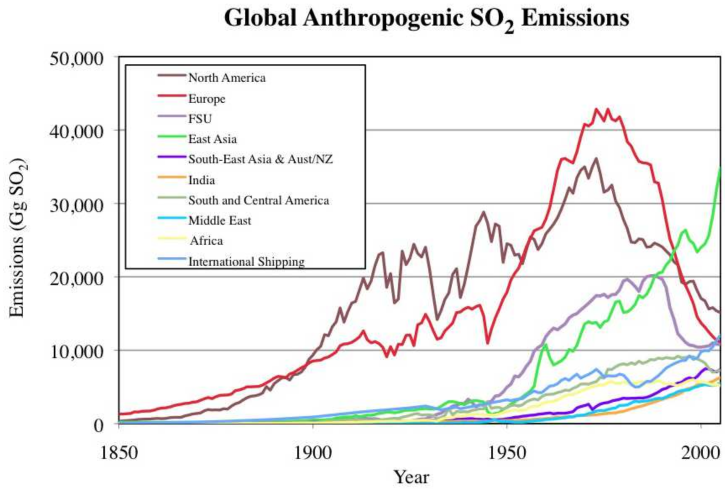


Figure 2. Global sulfur dioxide emissions by region (North America= USA + Canada; East Asia = Japan + China+ South Korea, FSU = Former Soviet Union). Figure taken from Smith et al. (Atmos. Chem. Phys., 1101-1116, 2011).

Effects of aerosol emission changes on atmospheric circulation

General circulation models are useful tools to understand the effects of a change in the overall magnitude or redistribution of aerosol particle emissions on climate. In Lewinschal et al. (2013) the fully coupled climate model EC-Earth2 was used to study the impact of aerosol direct radiative effects on stationary waves in the northern wintertime circulation. Comparing simulations with aerosol concentrations representing pre-industrial and present-day conditions, it was found that the imposed aerosol concentration change influenced convective precipitation, in particular in the tropics, which in turn modified the northern hemisphere stationary wave pattern. The main pattern of the wave change could be replicated by a linear, baroclinic model forced with latent heat changes corresponding to the precipitation anomalies generated by EC-Earth2. This result shows a causal connection between local aerosol emission changes and the general circulation through the precipitation anomalies. Note that the simulations by Lewinschal et al. (2013) did not include any direct relation between the aerosol concentration changes and cloud formation, i.e. the indirect aerosol effect was not considered.

Pausata et al. (2014) used a different climate model, ECHAM-HAM2 coupled to a mixed layer ocean, to examine the impact of a future maximum, feasible aerosol emission reduction in Europe on the wintertime atmospheric circulation over the North Atlantic. Assuming greenhouse gas and aerosol emissions representative for the year 2030, they found a more positive North Atlantic Oscillation mean state, a significant eastward shift of the southern center of action of the sea level pressure and a significantly increased blocking frequency over the western Mediterranean compared to present-day. Additional simulations showed that the dominant factor for inducing these circulation features was the decrease in aerosol emissions, not the increasing greenhouse gas concentrations over the same time period. Interestingly, the change in the blocking frequency due to decreasing aerosol forcing may in turn mean more episodes of stagnant weather in the future, which may favor air pollution accumulation in the boundary layer and occasionally higher concentrations of aerosol particles.

Effects of aerosol emission changes on the spatial distribution of temperature change

Several studies, including Lewinschal et al. (2013) and Bender et al. (2014), have shown that there is little resemblance between the radiative forcing pattern induced by aerosols and the corresponding surface temperature change. Instead, the spatial distribution of the surface temperature response induced by aerosols has often been noted to resemble a negative copy of the response induced by increasing greenhouse gas concentrations. Lewinschal et al. (2013) compared coupled ocean-atmosphere simulations with present-day and preindustrial aerosol concentrations. They found a strong correlation between the change in the stationary wave pattern at 300 hPa and the surface temperature response (Figure 3). Additional simulations using the CAM4-Oslo model coupled to a mixed layer ocean indicated that when forced with either increased greenhouse gas concentrations or changed aerosol emissions, the precipitation changes and thus the atmospheric circulation changes were similar, but of opposite sign, provided that the aerosol forcing was strong enough. If the spatial distribution of the surface temperature response is indeed strongly connected to circulation changes, this result could at least in part explain why previous studies have found similar temperature response patterns when the models have been forced by changes in either greenhouse gases or aerosols.

In a more recent study, the impact of the dramatic changes in European sulfur emissions at the end of the 20^{ht} century (cf. Fig. 2) on radiation, circulation and surface temperature has been examined (Acosta et al., in prep). The strong reduction in the sulfate burden over Europe was found to produce a positive radiative forcing over the same region. However, concurrent with the previous studies, the radiative perturbation anomaly did not induce a clear local temperature response. Instead, a wave response was generated in the model that affected the overall northward heat transport. The strongest response in the surface temperature was therefore seen in the Arctic region which warmed locally by more than 0.5^{o}C.

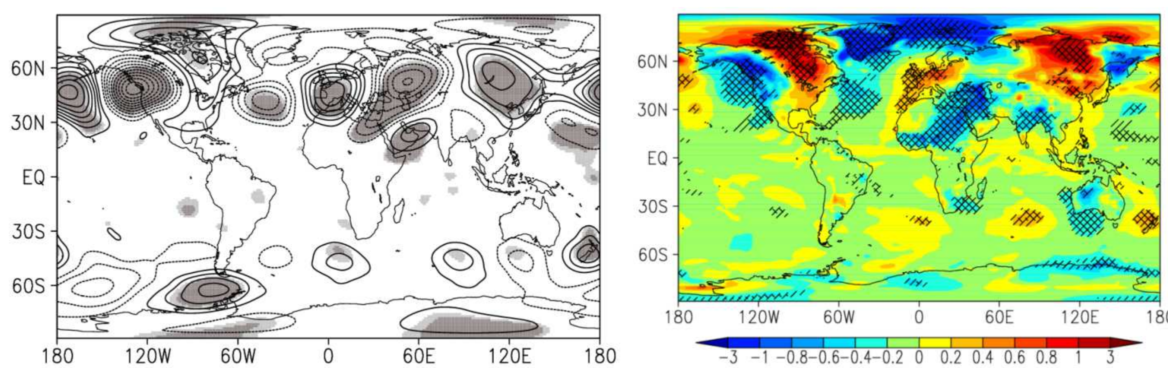


Figure 3. 300 hPa geopotential change (left) and 2m air temperature change (right) comparing a 40-year average from a coupled ocean-atmosphere simulation with present-day and preindustrial aerosol concentrations, respectively. Hatching and double hatching indicate significance at the 90 and 95% confidence level, respectively. From Lewinschal et al. (2013).

Summary and future directions

It is clear from the studies above that anthropogenic aerosol particle emissions, while altering the radiative balance, also affect atmospheric circulation patterns, both regionally and globally. However, it is possible that the circulation anomalies are model dependent and also that the mechanisms behind the circulation changes are related to the magnitude, location and type of forcing. Precipitation changes, in particular in the tropics, seem to be at least in part responsible for modifying the circulation, but the exactly how these precipitation anomalies are generated needs to be further investigated. Conducting more systematic studies, with different types of forcing perturbations located in different regions and using several different models, may be one way to provide more robust knowledge. Comparing simulated circulation trends with those obtained from reanalysis may also help us obtain more confidence in the results.

JET STREAM VARIABILITY AND CLIMATE

A. Hannachi and L. Chafik

Weather and climate vary on a wide range of space scales and also time scales, ranging from minutes to centuries. The dynamics of the earth's atmosphere is investigated by analysing the variability of many variables. For example, precipitation, surface temperature and surface winds are among the most important variables that are directly felt by humans and can affect our society and infrastructure.

Winds, which blow from west to east over most of the earth, are not homogeneous over the earth surface and across the atmospheric depth. For instance, the wind speed increases with height as one gets away from the surface friction. The most important observation, however, is the fact that the prevailing westerly winds are strongest in two belts located in the upper troposphere, referred to as jet streams. These are known as the subtropical and polar jets respectively. The former is caused by what is known as the conservation of angular momentum, i.e., earth spin, which is imparted to the atmosphere from the earth. The latter is associated with the edge of the polar front and is tightly linked to frontogenesis where baroclinic eddies are active in the midlatitudes. This front is, in fact, the boundary between the polar cold air and low-latitude warm air.

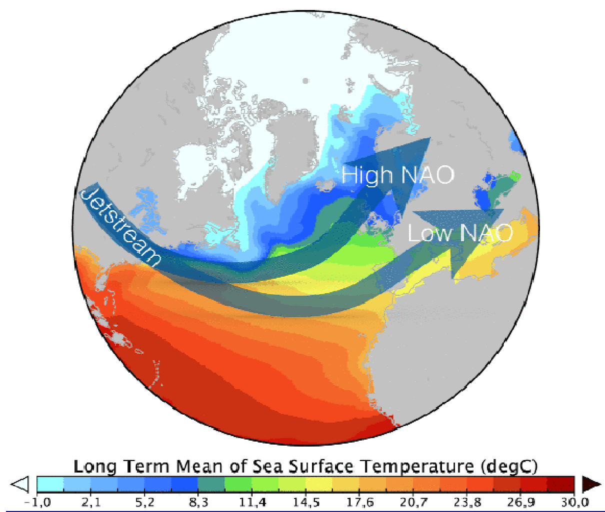


Figure 1: Climatological sea surface temperature (˚C) along with an illustration of the jet stream over the North Atlantic/European sector. During high (low) phases of the North Atlantic Oscillation the jet stream is shifted poleward (equatorward) of its climatological position.

The two jets interact strongly and in some cases coincide, as in the North Pacific. The (polar) jet stream, in particular, is associated with much of the weather and climate of the extratropics. The jet stream is normally identified by its strength and latitudinal position. A change in the position and/or strength of the jet stream strongly affects weather and climate and thus affects society and environment. The position of the jet stream, in particular, is closely associated with the large-scale having patterns of large scale high and low pressure anomalies over the northern hemisphere, known as North Atlantic Oscillation (NAO), East Atlantic (EA) and Scandinavian (SCAN) patterns. The NAO is the most dominant mode of climate variability over the north Atlantic and gives a measure of the strength of Azores subtropical high and Icelandic low pressure systems. The EA pattern is similar to the NAO except that its centre of action (low or high) is located over the eastern North Atlantic. For example, Figure 1 shows two positions of the jet stream over the North Atlantic European sector.

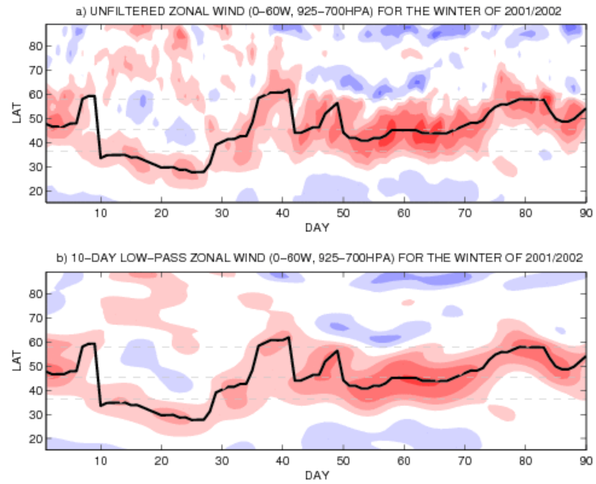


Figure 2: An example of the latitude-time evolution of the unfiltered (a) and low-pass filtered (b) westerly wind averaged over the longitudes 0-60˚ W and pressure levels 925-700 mb from the ECMWF reanalyses (ERA-40) winter 2001/2002. The black line refers to the centre of the jet. The latitudes of the preferred jet positions are shown by dashed lines. The contour interval is 5 m/s, negative contours are dashed and the zero line is omitted.

The analysis of the jet stream over the North Atlantic shows that the jet has three preferred latitudinal locations, namely, the southern, central and northern positions (Fig. 2). The jet can persist in those latitudes for an extended period of time. Each position is associated with a particular flow (Fig. 3). For instance when the winter jet is in its southern position a high pressure forms over Greenland, known as Greenland blocking, and induces extreme cold weather over Scandinavia and northern Europe in winter. When the jet is in its northern position one gets mild and wet weather conditions coming from the North Atlantic and reaching northern Europe.

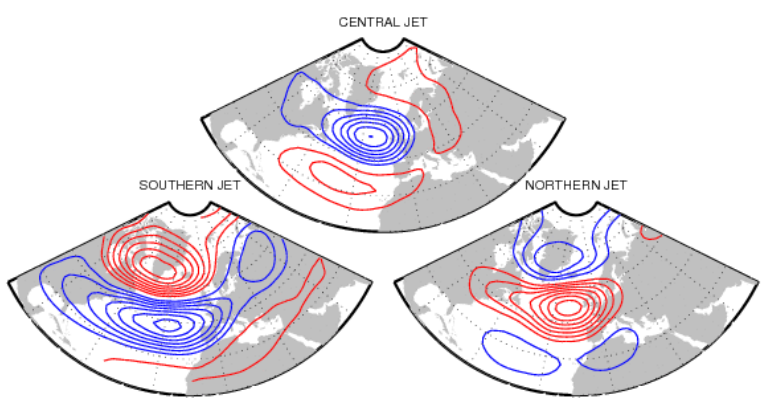


Figure 3: The 500-mb geopotential height anomaly flows associated with the preferred latitudinal jet stream positions. Red contours (high pressure) correspond to anticyclonic circulation.

The jet stream interacts with the North Atlantic ocean via wind stress and air-sea exchange. For example, blocking flow can lead to anomalies of ocean warming, which can have a positive feedback on atmospheric flow. Another important player in the jet variability is the Arctic sea ice. The persistence of the jet stream in a particular position can affect the growth/decay of Arctic sea ice. Conversely, Arctic sea ice variability can act to shift the jet stream and can thus affect weather/climate in the midlatitudes in various ways. For example, there is a positive correlation between temperature variability in Barents-Kara sea and Eurasian blocking.

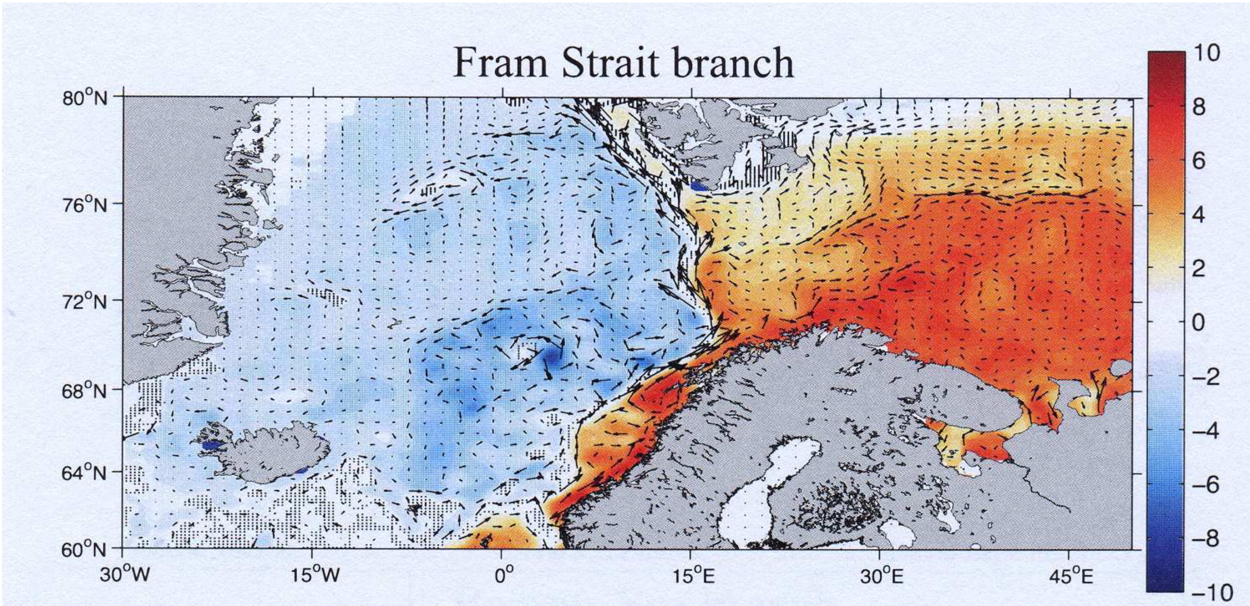


Figure 4: Composite of SSH and associated velocity field based on the difference between high and low transport months for the Fram strait branch, i.e. the current connecting the Nordic Seas to the Arctic Ocean

And Furthermore, the jet can, via wind stress, affect the volume of water transported. It is known that the Northern extension of the North Atlantic ocean current, aka, Norwegian Atlantic current, transports warm (and saline) Atlantic water poleward, thus bringing heat to Scandinavia and surroundings. The energy transported affects directly the Barents Sea and the Arctic Ocean. Figure 4 shows a composite of sea surface height (SSH) and the associated velocity obtained from the difference between high and low SSH months for the Fram Strait branch (west of Svalbard). The figure shows coherent structures in this branch. These flow anomalies are linked to the prevailing wind system associated with NAO, EA and SCAN patterns. In particular, a combination of the positive phases of NAO and SCAN are the main drivers of anomalously high water transport (and vice-versa for the negative phases) towards the Arctic. The positive EA pattern seems to be the driver of anomalously low transport into the Barents Sea. In wintertime, in particular, the NAO seems to control most of the transport in the Fram Strait branch, whereas SCAN mainly controls the Barents Sea transport. So, understanding the variability of the heat transported to the Arctic and Barents Sea by the large-scale ocean currents requires more knowledge of the variability of the North Atlantic jet stream.

Given that the persistence and meridional shifts of the jet stream dictate to a great extent what the synoptic pattern is likely to be, an improved understanding of the jet behaviour is central to understanding extratropical weather and climate predictability.

Climate models are the only tools available to climate scientists to analyse weather and climate dynamics on intra-seasonal and inter-annual and longer time scales, and to study past, present and future variability. The Climate Model Intercomparison Project (CMIP) is a major contributor to the World Climate Research Programme (WCRP). Data from climate model simulations for past, present and future were collected in 2005-2006, making the phase 3 of CMIP, i.e. CMIP3, where around 50 climate simulations were archived. For the next phase the WCRP working group updated the archive collecting around 20 simulations from updated climate models making the 5'th phase CMIP5.

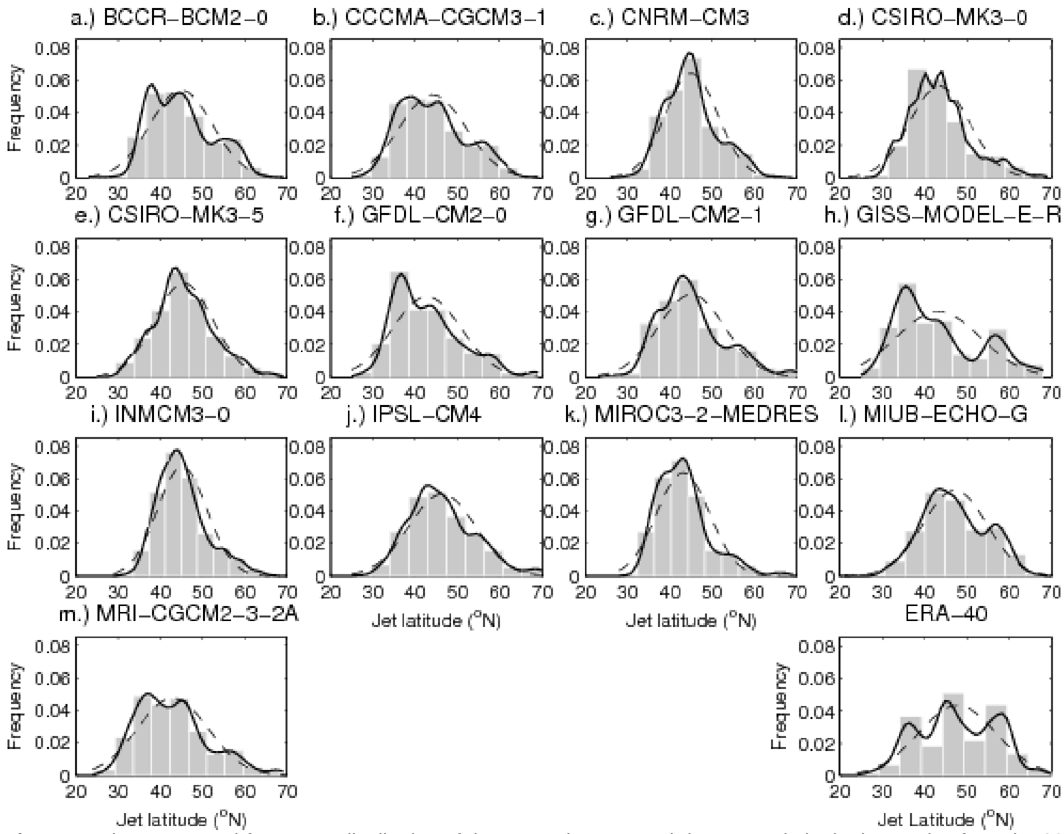


Figure 5: Histograms and frequency distribution of the December-to-March jet stream latitude time series from the 20C3M simulations. The same plot for ECMWF (ERA40) reanalyses is shown in the right bottom corner.

The analysis of the North Atlantic jet stream latitude from CMIP3 shows that the majority of climate models do not reproduce the three preferred positions obtained using observations, or more precisely reanalyses, from the European Centre for Medium Weather Forecasting (ECMWF). Figure 5 shows an example of the frequency distribution of the jet latitude of the 20'th Century Climate Experiment (20C3M) from CMIP3 simulations for the period 1961-2000. The same plot from the reanalyses is also shown. A few models do modestly pick up the observed feature of the jet latitude, namely the Bjerknes centre for Climate Research (Fig 5a), the Meteorological Research Institute (Fig. 5m) and to some extent NASA/Goddard Institute for Space Studies.

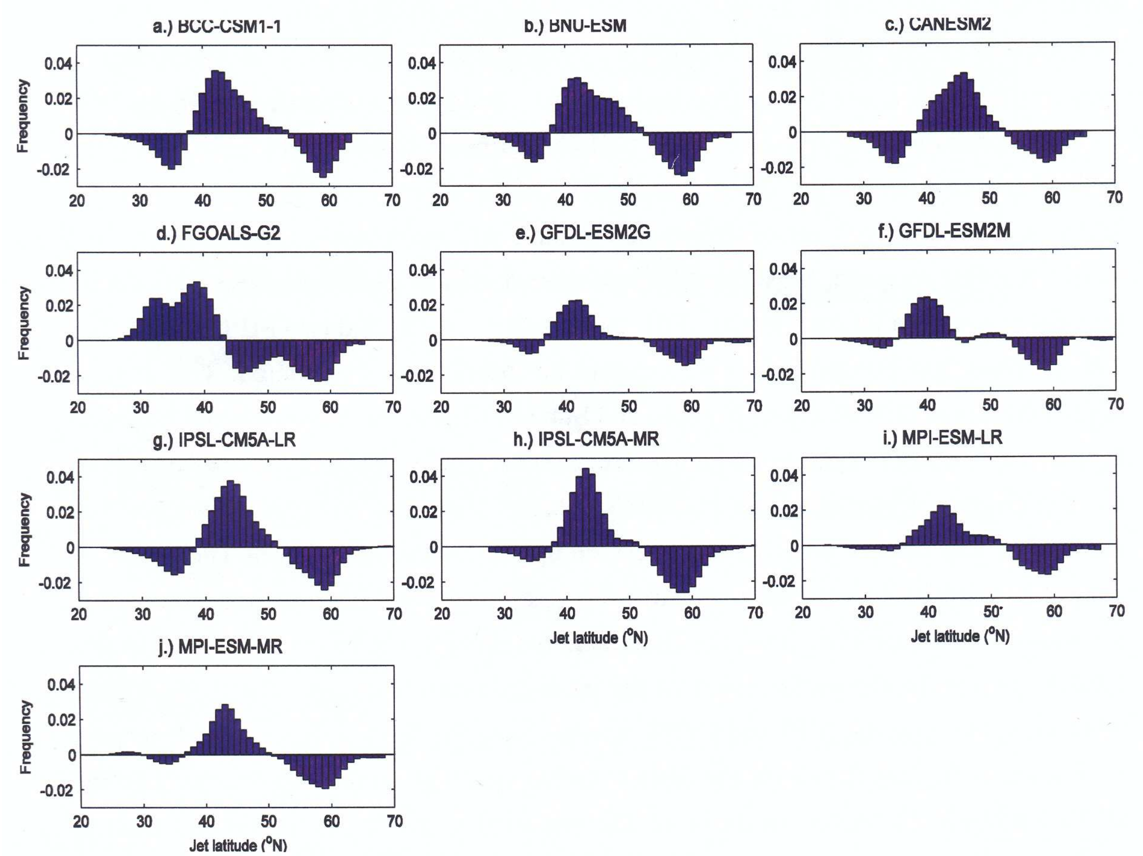


Figure 6: Difference between jet latitude frequency distributions of CMIP5 20C3M simulations and that of the ECMWF reanalyses in this geometry.

Results from CMIP5 do not show a noticeable improvement in simulating the jet stream. Fig. 6 shows the difference between jet latitude frequency of the 20C3M of a number of CMIP5 simulations and that of ECMWF reanalyses shown in Fig. 5 (bottom right corner). Most of these models over-estimate the central jet whereas the northern and southern jets are reduced and sometimes absent.

The results from model simulations for all emission scenarios suggest that the frequency of the jet latitude becomes more unimodal, that is the warming induces further decrease of the frequency of the southern and northern jet positions, but the frequency becomes bulged poleward. This is in agreement with the fact that jet stream tends to move poleward under global warming. We have to consider, of course, the fact that climate models have various biases in the representation of the present climate. It is possible that climatological and seasonal biases of the models could be the reason for the observed disagreement with the reanalyses in representing the jet stream variability. Furthermore, in most CMIP3 and CMIP5 climate models, the physical stratospheric processes are rather crude. For example, the chemistry in the stratosphere is prescribed, i.e. the chemical compounds are not interactive. It is likely that the lack of a full representation of the stratospheric processes affects the interaction with the troposphere and consequently can affect the jet dynamics.

LIST OF PUBLICATIONS

2013

Achtert, P., Khaplanov, M., Khosrawi, F. & Gumbel, J. (2013). Pure rotational-Raman channels of the Esrange lidar for temperature and particle extinction measurements in the troposphere and lower stratosphere. Atmospheric Measurement Techniques, 6(1), 91-98.

Bahrami, F., Taghvafard, H., Nycander, J. & Mohammadi, A. (2013). Stability investigation for steady solutions of the barotropic vorticity equation in R-2. Communications in Nonlinear Science & Numerical Simulation, 18(3), 541-546.

Ballarotta, M., Drijfhout, S., Kuhlbrodt, T. & Döös, K. (2013). The residual circulation of the Southern Ocean: Which spatio-temporal scales are needed? Ocean Modelling, 64, 46-55.

Ballarotta, M., Laurent, B., Jenny, B., Lundberg, P. & Döös, K. (2013). Last Glacial Maximum world ocean simulations at eddy-permitting and coarse resolutions: do eddies contribute to a better consistency between models and palaeoproxies?. Climate of the Past, 9(6), 2669-2686.

Bari, D. D., Gabriel, A., Kornich, H. & Peters, D. W. (2013). The effect of zonal asymmetries in the Brewer-Dobson circulation on ozone and water vapor distributions in the northern middle atmosphere. Journal of Geophysical Research - Atmospheres, 118(9), 3447-3466.

Berger, M., Brandefelt, J. & Nilsson, J. (2013). The sensitivity of the Arctic sea ice to orbitally induced insolation changes: a study of the mid-Holocene Paleoclimate Modelling Intercomparison Project 2 and 3 simulations. Climate of the Past, 9(2), 969-982.

Caballero, R. & Huber, M. (2013). State-dependent climate sensitivity in past warm climates and its implications for future climate projections. Proceedings of the National Academy of Sciences of the United States of America, 110(35), 14162-14167.

Caron, L.-P., Jones, C. G., Vaillancourt, P. A. & Winger, K. (2013). On the relationship between cloud-radiation interaction, atmospheric stability and Atlantic tropical cyclones in a variable-resolution climate model. Climate Dynamics, 40(5-6), 1257-1269.

Casella, D., Panegrossi, G., Sano, P., Dietrich, S., Mugnai, A., Smith, E. A. & Mehta, A. V. (2013). Transitioning From CRD to CDRD in Bayesian Retrieval of Rainfall From Satellite Passive Microwave Measurements: Part 2. Overcoming Database Profile Selection Ambiguity by Consideration of Meteorological Control on Microphysics. IEEE Transactions on Geoscience and Remote Sensing, 51(9), 4650-4671.

Chen, H. W., Zhang, Q., Körnich, H. & Chen, D. (2013). A robust mode of climate variability in the Arctic: The Barents Oscillation. Geophysical Research Letters, 40(11), 2856-2861.

Claesson, J. & Nycander, J. (2013). Combined effect of global warming and increased CO_2-concentration on vegetation growth in water-limited conditions. Ecological Modelling, 256, 23-30.

Corell, H. & Döös, K. (2013). Difference in Particle Transport Between Two Coastal Areas in the Baltic Sea Investigated with High-Resolution Trajectory Modeling. Ambio, 42(4), SI 455-463.

de Boer, A. M., Collier, A. B. & Caballero, R. (2013). Processes driving thunderstorms over the Agulhas

Current. Journal of Geophysical Research-Atmospheres, 118(5), 2220-2228.

Efrati, S., Lehahn, Y., Rahav, E., Kress, N., Herut, B., Gertman, I. & .
Heifetz, E. (2013). Intrusion of coastal waters into the pelagic eastern Mediterranean: in situ and satellite-based characterization. Biogeosciences, 10(5), 3349-3357.

Eilola, K., Mårtensson, S. & Meier, M. (2013). Modeling the impact of reduced sea ice cover in future climate on the Baltic Sea biogeochemistry. Geophysical Research Letters, 40(1), 149-154.

El-Hames, A. S., Hannachi, A., Al-Ahmadi, M. & Al-Amri, N. (2013). Groundwater Quality Zonation Assessment using GIS, EOFs and Hierarchical Clustering. Water Resources Management, 27(7), 2465-2481.

Goldner, A., Huber, M. & Caballero, R. (2013). Does Antarctic glaciation cool the world? Climate of the Past, 9(1), 173-189.

Green, J. A. & Nycander, J. (2013). A comparison of tidal conversion parameterizations for tidal models. Journal of Physical Oceanography, 43(1), 104-119.

Hamacher-Barth, E., Jansson, K. & Leck, C. (2013). A method for sizing submicrometer particles in air collected on Formvar films and imaged by scanning electron microscopy. Atmospheric Measurement Techniques, 6(12), 3459-3475.

Hannachi, A., Barnes, E. A. & Woollings, T. (2013). Behaviour of the winter North Atlantic eddy-driven jet stream in the CMIP3 integrations. Climate Dynamics, 41(3-4), 995-1007.

Hannachi, A. & Turner, A. G. (2013). 20th century intraseasonal Asian monsoon dynamics viewed from Isomap. Nonlinear Processes in Geophysics, 20(5), 725-741.

Hannachi, A. & Turner, A. G. (2013). Isomap nonlinear dimensionality reduction and bimodality of Asian monsoon convection. Geophysical Research Letters, 40(8), 1653-1658.

Hede, T., Leck, C., Sun, L., Tu, Y. & Ågren, H. (2013). A theoretical study revealing the promotion of light absorbing carbon particles solubilization by natural surfactants in nanosized water droplets. Atmospheric Science Letters, 14(2), 86-90.

Hieronymus, J. & Walin, G. (2013). Unravelling the land source: an investigation of the processes contributing to the oceanic input of DIC and alkalinity. Tellus. Series B, Chemical and Physical Meteorology, 65, 19683.

Hieronymus, M. & Nycander, J. (2013). The buoyancy budget with a nonlinear equation of state. Journal of Physical Oceanography, 43(1), 176-186.

Hieronymus, M. & Nycander, J. (2013). The budgets of heat and salinity in NEMO. Ocean Modelling, 67, 28-38.

Holtslag, A. A., Svensson, G., Baas, P., Basu, S., Beare, B., Beljaars, A. C., Van de Wiel, B. J. (2013). Stable atmospheric boundary layers and diurnal cycles: Challenges for weather and climate models. Bulletin of the American Meteorological Society, 94(11), 1691-1706.

Huck, P. E., Bodeker, G. E., Kremser, S., McDonald, A. J., Rex, M. & Struthers, H. (2013). Semi-empirical models for chlorine activation and ozone depletion in the Antarctic stratosphere: proof of concept. Atmospheric Chemistry and Physics, 13(6), 3237-3243.

Hultgren, K., Gumbel, J., Degenstein, D., Bourassa, A., Lloyd, N. & Stegman, J. (2013). First simultaneous retrievals of horizontal and vertical structures of Polar Mesospheric Clouds from Odin/OSIRIS tomography. Journal of Atmospheric and Solar-Terrestrial Physics, 104, 213-223.

Kapsch, M.-L., Graversen, R. G. & Tjernström, M. (2013). Springtime atmospheric energy transport and the control of Arctic summer sea-ice extent. Nature Climate Change, 3(8), 744-748.

Karl, M., Leck, C., Coz, E. & Heintzenberg, J. (2013). Marine nanogels as a source of atmospheric nanoparticles in the high Arctic. Geophysical Research Letters, 40(14), 3738-3743.

Karlsson, J. & Svensson, G. (2013). Consequences of poor representation of Arctic sea-ice albedo and cloud-radiation interactions in the CMIP5 model ensemble. Geophysical Research Letters, 40(16), 4374-4379.

Khosrawi, F., Mueller, R., Urban, J., Proffitt, M. H., Stiller, G., Kiefer, M., Murtagh, D. (2013). Assessment of the interannual variability and influence of the QBO and upwelling on tracer-tracer distributions of N_2O and O_3 in the tropical lower stratosphere. Atmospheric Chemistry and Physics, 13(7), 3619-3641.

Kirkevag, A., Iversen, T., Seland, O., Hoose, C., Kristjansson, J. E., Struthers, H., Schulz, M. (2013). Aerosol-climate interactions in the Norwegian Earth System Model-NorESM1-M. Geoscientific Model Development, 6(1), 207-244.

Kjellström, E., Thejll, P., Rummukainen, M., Christensen, J. H., Boberg, F., Christensen, O. B. & Maule, C. F. (2013). Emerging regional climate change signals for Europe under varying large-scale circulation conditions. Climate Research, 56(2), 103-119.

Kleman, J., Fastook, J., Ebert, K., Nilsson, J. & Caballero, R. (2013). Pre-LGM Northern Hemisphere ice sheet topography. Climate of the Past, 9, 2365-2378.

Koenigk, T. & Brodeau, L. (2013). Ocean heat transport into the Arctic in the twentieth and twenty-first century in EC-Earth. Climate Dynamics, 42(11-12), 3101-3120.

Kupiszewski, P., Leck, C., Tjernström, M., Sjögren, S., Sedlar, J., Graus, M., Hansel, A. (2013). Vertical profiling of aerosol particles and trace gases over the central Arctic Ocean during summer. Atmospheric Chemistry and Physics, 13(24), 12405-12431.

Lazar, A., Stegner, A. & Heifetz, E. (2013). Inertial instability of intense stratified anticyclones. Part 1. Generalized stability criterion. Journal of Fluid Mechanics, 732, 457-484.

Leck, C., Gao, Q., Mashayekhy Rad, F. & Nilsson, U. (2013). Size-resolved atmospheric particulate polysaccharides in the high summer Arctic. Atmospheric Chemistry and Physics, 13(24), 12573-12588.

Lewinschal, A., Ekman, A. M. L. & Körnich, H. (2013). The role of precipitation in aerosol-induced changes in Northern Hemisphere wintertime stationary waves. Climate Dynamics, 41(3-4), 647-661.

Li, X., Hede, T., Tu, Y., Leck, C. & Ågren, H. (2013). Cloud droplet activation mechanisms of amino acid aerosol particles: insight from molecular dynamics simulations. Tellus. Series B, Chemical and Physical Meteorology, 65, 20476.

Li, X., Leck, C., Sun, L., Hede, T., Tu, Y. & Ågren, H. (2013). Cross-linked polysaccharide assemblies in marine gels: an atomistic simulation. Journal of Physical Chemistry Letters, 4(16), 2637-2642.

Lindvall, J., Svensson, G. & Hannay, C. (2013). Evaluation of near surface parameters in the two versions of the atmospheric model in CESM1 using flux station observations. Journal of Climate, 26(1), 26-44.

Liu, Y., Meier, H. E. & Axell, L. (2013). Reanalyzing temperature and salinity on decadal time scales using the ensemble optimal interpolation data assimilation method and a 3D ocean circulation model of the Baltic Sea. Journal of Geophysical Research - Oceans, 118(10), 5536-5554.

Mauritsen, T., Graversen, R. G., Klocke, D., Langen, P. L., Stevens, B. & Tomassini, L. (2013). Climate feedback efficiency and synergy. Climate Dynamics, 41(9-10), 2539-2554.

Melet, A., Nikurashin, M., Muller, C., Falahat, S., Nycander, J., Timko, P. G., Goff, J. A. (2013). Internal tide generation by abyssal hills using analytical theory. Journal of Geophysical Research - Oceans and Atmospheres, 118(11), 6303-6318.

Neu, U., Akperov, M. G., Bellenbaum, N., Benestad, R. S., Blender, R., Caballero, R., Wernli, H. (2013). IMILAST: A community effort to intercompare extratropical cyclone detection and tracking algorithms. Bulletin of the American Meteorological Society, 94(4), 529-547.

Nilsson, J. A. U., Döös, K., Ruti, P. M., Artale, V., Coward, A. & Brodeau, L. (2013). Observed and modeled global ocean turbulence regimes as deduced from surface trajectory data. Journal of Physical Oceanography, 43(11), 2249-2269.

Nilsson, J., Langen, P. L., Ferreira, D. & Marshall, J. (2013). Ocean basin geometry and the salinification of the Atlantic Ocean. Journal of Climate, 26(16), 6163-6184.

Ohshima, K. I., Fukamachi, Y., Williams, G. D., Nihashi, S., Roquet, F., Kitade, Y., Wakatsuchi, M. (2013). Antarctic BottomWater production by intense sea-ice formation in the Cape Darnley polynya. Nature Geoscience, 6(3), 235-240.

Ranjha, R., Svensson, G., Tjernström, M. & Semedo, A. (2013). Global distribution and seasonal variability of coastal low-level jets derived from ERA-Interim reanalysis. Tellus. Series A, Dynamic Meteorology and Oceanography, 65, 20412.

Reid, W., Achtert, P., Ivchenko, N., Magnusson, P., Kuremyr, T., Shepenkov, V. & Tibert, G. (2013). Technical Note: A novel rocket-based in situ collection technique for mesospheric and stratospheric aerosol particles. Atmospheric Measurement Techniques, 6(3), 777-785.

Roquet, F. (2013). Dynamical Potential Energy: A new approach to ocean energetics. Journal of Physical Oceanography, 43(2), 457-476.

Roquet, F., Wunsch, C., Forget, G., Heimbach, P., Guinet, C., Reverdin, G. & Fedak, M. A. (2013). Estimates of the Southern Ocean general circulation improved by animal-borne instruments. Geophysical Research Letters, 40(23), 6176-6180.

Salih, A. A. M., Körnich, H. & Tjernström, M. (2013). Climate impact of deforestation over South Sudan in a regional climate model. International Journal of Climatology, 33(10), 2362-2375.

Shupe, M. D., Persson, P. O., Brooks, I. M., Tjernström, M., Sedlar, J., Mauritsen, T. & Leck, C. (2013). Cloud and boundary layer interactions over the Arctic sea ice in late summer. Atmospheric Chemistry and Physics, 13(18), 9379-9399.

Smith, E. A., Leung, W. Y. H. & Sano, P. (2013). Transitioning from CRD to CDRD in Bayesian retrieval of rainfall from satellite passive microwave measurements: Part 3 - Identification of optimal meteorological tags. Natural Hazards and Earth System Sciences, 13(5), 1185-1208.

Sriver, R., Matthew, H. & Chafik, L. (2013). Excitation of equatorial Kelvin and Yanai waves by tropical cyclones in an ocean general circulation model. Earth System Dynamics, 4(1), 1-10.

Struthers, H., Ekman, A., Glantz, P., Iversen, T., Kirkevag, A., Seland, O. & Nilsson, E. D. (2013). Climate-induced changes in sea salt aerosol number emissions: 1870 to 2100. Journal of Geophysical Research - Atmospheres, 118(2), 670-682.

Sun, L., Hede, T., Tu, Y., Leck, C. & Ågren, H. (2013). Combined effect of glycine and sea salt on aerosol cloud droplet activation predicted by molecular dynamics simulations. Journal of Physical Chemistry A, 117(41), 10746-10752.

Turnewitsch, R., Falahat, S., Nycander, J., Dale, A., Scott, R. B. & Furnival, D. (2013). Deep-sea fluid and sediment dynamics: Influence of hill- to seamount-scale seafloor topography. Earth-Science Reviews, 127, 203-241.

Vogt, M., Johansson, C., Mårtensson, M., Struthers, H., Ahlm, L. & Nilsson, D. (2013). Heated submicron particle fluxes using an optical particle counter in urban environment. Atmospheric Chemistry and Physics, 13(6), 3087-3096.

Woods, C., Caballero, R. & Svensson, G. (2013). Large-scale circulation associated with moisture intrusions into the Arctic during winter. Geophysical Research Letters, 40(17), 4717-4721.

Zabori, J., Krejci, R., Ström, J., Vaattovaara, P., Ekman, A., Salter, M., Nilsson, D. (2013). Comparison between summertime and wintertime Arctic Ocean primary marine aerosol properties. Atmospheric Chemistry and Physics, 13(9), 4783-4799.

Zhang, Q., Körnich, H. & Holmgren, K. (2013). How well do reanalyses represent the southern African precipitation? Climate Dynamics, 40(3-4), 951-962.

2014

Achtert, P. & Tesche, M. (2014). Assessing LIDAR-based classification schemes for polar stratospheric clouds based on 16 years of measurements at Esrange, Sweden. Journal of Geophysical Research - Atmospheres, 119(3), 1386-1405.

Acosta Navarro, J. C., Smolander, S., Struthers, H., Zorita, E., Ekman, A. M. L., Kaplan, J. O. & Riipinen, I. (2014). Global emissions of terpenoid VOCs from terrestrial vegetation in the last millennium. Journal of Geophysical Research - Atmospheres, 119(11), 6867-6885.

Ballarotta, M., Falahat, S., Brodeau, L. & Döös, K. (2014). On the glacial and interglacial thermohaline circulation and the associated transports of heat and freshwater. Ocean Science, 10(6), 907-921.

Belova, E., Kirkwood, S., Latteck, R., Zecha, M., Pinedo, H., Hedin, J. & Gumbel, J. (2014). Multi-radar observations of polar mesosphere summer echoes during the PHOCUS campaign on 20-22 July 2011. Journal of Atmospheric and Solar-Terrestrial Physics, 118, 199-205.

Booth, A. M., Murphy, B., Riipinen, I., Percival, C. J. & Topping, D. O. (2014). Connecting bulk viscosity measurements to kinetic limitations on attaining equilibrium for a model aerosol composition. Environmental Science and Technology, 48(16), 9298-9305.

Bosveld, F. C., Baas, P., Steeneveld, G.-J., Holtslag, A. A. M., Angevine, W. M., Bazile, E. & Svensson, G. (2014). The third GABLS intercomparison case for evaluation studies of boundary-layer models. Part B: results and process understanding. Boundary-layer Meteorology, 152(2), 157-187.

Brown, L. C., Howell, S. E. L., Mortin, J. & Derksen, C. (2014). Evaluation of the Interactive Multisensor Snow and Ice Mapping System (IMS) for monitoring sea ice phenology. Remote Sensing of Environment, 147, 65-78.

Browse, J., Carslaw, K. S., Mann, G. W., Birch, C. E., Arnold, S. R. & Leck, C. (2014). The complex response of Arctic aerosol to sea-ice retreat. Atmospheric Chemistry and Physics, 14(14), 7543-7557.

Budhavant, K. B., Rao, P. S., Safai, P. D., Granat, L. & Rodhe, H. (2014). Chemical composition of the inorganic fraction of cloud-water at a high altitude site in West India. Atmospheric Environment, 88, 59-65.

Caron, L.-P., Jones, C. G. & Doblas-Reyes, F. (2014). Multi-year prediction skill of Atlantic hurricane activity in CMIP5 decadal hindcasts. Climate Dynamics, 42(9-10), 2675-2690.

Chafik, L., Rossby, T. & Schrum, C. (2014). On the spatial structure and temporal variability of poleward transport between Scotland and Greenland. Journal of Geophysical Research - Oceans, 119(2), 824-841.

Cuthbertson, A. J., Lundberg, P., Davies, P. A. & Laanearu, J. (2014). Gravity currents in rotating, wedge-shaped, adverse channels. Environmental Fluid Mechanics, 14(5), 1251-1273.

Dawkins, E. C., Plane, J. M., Chipperfield, M. P., Feng, W., Gumbel, J., Hedin, J. & Friedman, J. S. (2014). First global observations of the mesospheric potassium layer. Geophysical Research Letters, 41(15), 5653-5661.

de Boer, G., Shupe, M. D., Caldwell, P. M., Bauer, S. E., Persson, O., Boyle, J. S. & Tjernström, M. (2014). Near-surface meteorology during the Arctic Summer Cloud Ocean Study (ASCOS): evaluation of reanalyses and global climate models. Atmospheric Chemistry and Physics, 14(1), 427-445.

Decremer, D., Chung, C. E., Ekman, A. M. L. & Brandefelt, J. (2014). Which significance test performs the best in climate simulations? Tellus Series A, Dynamic Meteorology and Oceanography, 66, 23139.

Ehard, B., Achtert, P. & Gumbel, J. (2014). Long-term lidar observations of wintertime gravity wave activity over northern Sweden. Annales Geophysicae, 32(11), 1395-1405.

Eilola, K., Almroth-Rosell, E. & Meier, H. E. (2014). Impact of saltwater inflows on phosphorus cycling and eutrophication in the Baltic Sea: a 3D model study. Tellus. Series A, Dynamic Meteorology and Oceanography, 66, 23985.

Ekman, A. M. L. (2014). Do sophisticated parameterizations of aerosol-cloud interactions in CMIP5 models improve the representation of recent observed temperature trends? Journal of Geophysical Research - Atmospheres, 119(2), 817-832.

Engström, A., Bender, F.-M. A. & Karlsson, J. (2014). Improved Representation of Marine Stratocumulus Cloud Shortwave Radiative Properties in the CMIP5 Climate Models. Journal of Climate, 27(16), 6175-6188.

Engström, A., Karlsson, J. & Svensson, G. (2014). The importance of representing mixed-phase clouds for simulating distinctive atmospheric states in the Arctic. Journal of Climate, 27(1), 265-272.

Falahat, S., Nycander, J., Roquet, F., Thurnherr, A. M. & Hibiya, T. (2014). Comparison of calculated energy flux of internal tides with microstructure measurements. Tellus. Series A, Dynamic Meteorology and Oceanography, 66, 23240.

Falahat, S., Nycander, J., Roquet, F. & Zarroug, M. (2014). Global calculation of tidal energy conversion into vertical normal modes. Journal of Physical Oceanography, 44(12), 3225-3244.

Friman, M. & Strandberg, G. (2014). Historical responsibility for climate change: Science and the science-policy interface. Wiley Interdisciplinary Reviews: Climate Change, 5(3), 297-316.

Glantz, P., Bourassa, A., Herber, A., Iversen, T., Karlsson, J., Kirkevag, A. & Thomason, L. (2014). Remote sensing of aerosols in the Arctic for an evaluation of global climate model simulations. Journal of Geophysical Research - Atmospheres, 119(13), 8169-8188.

Graversen, R. G., Langen, P. L. & Mauritsen, T. (2014). Polar amplification in CCSM4: Contributions from the lapse rate and surface albedo feedbacks. Journal of Climate, 27(12), 4433-4450.

Hannachi, A. (2014). Intermittency, autoregression and censoring: a first-order AR model for daily precipitation. Meteorological Applications, 21(2), 384-397.

Harnik, N., Dritschel, D. G. & Heifetz, E. (2014). On the equilibration of asymmetric barotropic instability. Quarterly Journal of the Royal Meteorological Society, 140(685), 2444-2464.

Havnes, O., Gumbel, J., Antonsen, T., Hedin, J. & La Hoz, C. (2014). On the size distribution of collision fragments of NLC dust particles and their relevance to meteoric smoke particles. Journal of Atmospheric and Solar-Terrestrial Physics, 118, 190-198.

Hede, T., Murugan, N. A., Kongsted, J., Leck, C. & Ågren, H. (2014). Simulations of light absorption of carbon particles in nanoaerosol clusters. Journal of Physical Chemistry A, 118(10), 1879-1886.

Hedin, J., Giovane, F., Waldemarsson, T., Gumbel, J., Blum, J., Stroud, R. M. & Horanyi, M. (2014). The MAGIC meteoric smoke particle sampler. Journal of Atmospheric and Solar-Terrestrial Physics, 118, 127-144.

Heifetz, E. & Caballero, R. (2014). An alternative view on the role of the beta-effect in the Rossby wave propagation mechanism. Tellus. Series A, Dynamic Meteorology and Oceanography, 66, 22672.

Hieronymus, M. (2014). A note on the influence of spatially varying diffusivities on the evolution of buoyancy with a nonlinear equation of state. Journal of Physical Oceanography, 44(12), 3255-3261.

Hieronymus, M., Nilsson, J. & Nycander, J. (2014). Water Mass Transformation in Salinity Temperature Space. Journal of Physical Oceanography, 44(9), 2547-2568.

Hultgren, K. & Gumbel, J. (2014). Tomographic and spectral views on the lifecycle of polar mesospheric clouds from Odin/OSIRIS. Journal of Geophysical Research - Atmospheres, 119(24), 14129-14143.

Josey, S. A., Yu, L., Gulev, S., Jin, X., Tilinina, N., Barnier, B. & Brodeau, L. (2014). Unexpected impacts of the Tropical Pacific array on reanalysis surface meteorology and heat fluxes. Geophysical Research Letters, 41(17), 6213-6220.

Kapsch, M.-L., Graversen, R. G., Economou, T. & Tjernström, M. (2014). The importance of spring atmospheric conditions for predictions of the Arctic summer sea ice extent. Geophysical Research Letters, 41(14), 5288-5296.

Karlsson, J. & Teixeira, J. (2014). A simple model of the northeast Pacific stratocumulus to cumulus transition based on the climatological surface energy budget. Journal of Climate, 27(11), 4111-4121.

Kim, D., Wang, C., Ekman, A. M. L., Barth, M. C. & Lee, D.-I. (2014). The responses of cloudiness to the direct radiative effect of sulfate and carbonaceous aerosols. Journal of Geophysical Research: Atmospheres, 119(3), 1172-1185.

Kjellsson, J., Döös, K., Laliberté, F. B. & Zika, J. (2014). The atmospheric general circulation in thermodynamical coordinates. Journal of Atmospheric Sciences, 71(3), 916-928.

Löfverström, M., Caballero, R., Nilsson, J. & Kleman, J. (2014). Evolution of the large-scale atmospheric circulation in response to changing ice sheets over the last glacial cycle. Climate of the Past, 10(4), 1453-1471.

Mortin, J., Graversen, R. G. & Svensson, G. (2014). Evaluation of pan-Arctic melt-freeze onset in CMIP5 climate models and reanalyses using surface observations. Climate Dynamics, 42(7-8), 2239-2257.

Mortin, J., Howell, S. E. L., Wang, L., Derksen, C., Svensson, G., Graversen, R. G. & Schrøder, T. M. (2014). Extending the QuikSCAT record of seasonal melt–freeze transitions over Arctic sea ice using ASCAT. Remote Sensing of the Environment, 141(5), 214-230.

Murphy, B. N., Donahue, N. M., Robinson, A. L. & Pandis, S. N. (2014). A naming convention for atmospheric organic aerosol. Atmospheric Chemistry and Physics, 14(11), 5825-5839.

Olivieri, S., Picano, F., Sardina, G., Iudicone, D. & Brandt, L. (2014). The effect of the Basset history force on particle clustering in homogeneous and isotropic turbulence. Physics of Fluids, 26(4), 041704.

Park, H., Chung, C. E., Ekman, A. M. L. & Choi, J.-O. (2014). Evaluation of ACCMIP simulated fine-mode AOD and its implication for aerosol direct forcing. Asia-Pacific Journal of Atmospheric Sciences, 50(3), 377-390.

Pemberton, P., Nilsson, J. & Meier, H. E. (2014). Arctic Ocean freshwater composition, pathways and transformations from a passive tracer simulation. Tellus. Series A, Dynamic Meteorology and Oceanography, 66, 23988.

Pinto, J. G., Gomara, I., Masato, G., Dacre, H. F., Woollings, T. & Caballero, R. (2014). Large-scale dynamics associated with clustering of extratropical cyclones affecting Western Europe. Journal of Geophysical Research - Atmospheres, 119(24), 13704-13719.

Plane, J. M. C., Saunders, R. W., Hedin, J., Stegman, J., Khaplanov, M., Gumbel, J. & Williams, B. P. (2014). A combined rocket-borne and ground-based study of the sodium layer and charged dust in the upper mesosphere. Journal of Atmospheric and Solar-Terrestrial Physics, 118, 151-160.

Rosenberg, P. D., Parker, D. J., Ryder, C. L., Marsham, J. H., Garcia-Carreras, L., Dorsey, J. R., & Washington, R. (2014). Quantifying particle size and turbulent scale dependence of dust flux in the Sahara using aircraft measurements. Journal of Geophysical Research - Atmospheres, 119(12), 7577-7598.

Russell, J. M., Rong, P., Hervig, M. E., Siskind, D. E., Stevens, M. H., Bailey, S. M. & Gumbel, J. (2014). Analysis of northern midlatitude noctilucent cloud occurrences using satellite data and modeling. Journal of Geophysical Research - Atmospheres, 119(6), 3238-3250.

Savre, J., Ekman, A. M. L. & Svensson, G. (2014). Technical note: Introduction to MIMICA, a large-eddy simulation solver for cloudy planetary boundary layers. Journal of Advances in Modeling Earth Systems, 6(3), 630-649.

Schreier, M. M., Kahn, B. H., Suselj, K., Karlsson, J., Ou, S. C., Yue, Q. & Nasiri, S. L. (2014). Atmospheric parameters in a subtropical cloud regime transition derived by AIRS and MODIS: observed statistical variability compared to ERA-Interim. Atmospheric Chemistry and Physics, 14(7), 3573-3587.

Sedlar, J. (2014). Implications of limited liquid water path on static mixing within Arctic low-level clouds. Journal of Applied Meteorology and Climatology, 53(12), 2775-2789.

Sedlar, J. & Shurpe, M. D. (2014). Characteristic nature of vertical motions observed in Arctic mixed-phase stratocumulus. Atmospheric Chemistry and Physics, 14, 3461-3478.

Sierau, B., Chang, R.-W. Y., Leck, C., Paatero, J. & Lohmann, U. (2014). Single-particle characterization of the high-Arctic summertime aerosol. Atmospheric Chemistry And Physics, 14(14), 7409-7430.

Skyllakou, K., Murphy, B. N., Megaritis, A. G., Fountoukis, C. & Pandis, S. N. (2014). Contributions of local and regional sources to fine PM in the megacity of Paris. Atmospheric Chemistry And Physics, 14(5), 2343-2352.

Soares, P., Rita, C., Semedo, A., Chinita, M. & Ranjha, R. (2014). Climatology of Iberia coastal low-level wind jet: WRF high resolution results. Tellus. Series A, Dynamic Meteorology and Oceanography, 66, 22377.

Soomere, T., Döös, K., Lehmann, A., Meier, H. E., Murawski, J., Myrberg, K. & Stanev, E. (2014). The potential of current- and wind-driven transport for environmental management of the Baltic Sea. Ambio, 43(1), 94-104.

Sotiropoulou, G., Sedlar, J., Tjernström, M., Shupe, M. D., Brooks, I. M. & Persson, P. O. (2014). The thermodynamic structure of summer Arctic stratocumulus and the dynamic coupling to the surface. Atmospheric Chemistry and Physics, 14(22), 12573-12592.

Springer, A., Kusche, J., Hartung, K., Ohlwein, C. & Longuevergne, L. (2014). New estimates of variations in water flux and storage over europe based on regional (re)analyses and multisensor observations. Journal of Hydrometeorology, 15(6), 2397-2417.

Sternovsky, Z., Robertson, S., Dickson, S., Gumbel, J., Hedin, J., Strelnikov, B. & Havnes, O. (2014). In-situ detection of noctilucent cloud particles by the Colorado Dust Detectors onboard the PHOCUS sounding rocket. Journal of Atmospheric and Solar-Terrestrial Physics, 118, 145-150.

Strandberg, G., Kjellström, E., Poska, A., Wagner, S., Gaillard, M.-J., Trondman, A.-K., & Sugita, S. (2014). Regional climate model simulations for Europe at 6 and 0.2 k BP: sensitivity to changes in anthropogenic deforestation. Climate of the Past, 10(2), 661-680.

Thompson, B., Nycander, J., Nilsson, J., Jakobsson, M. & Döös, K. (2014). Estimating ventilation time scales using overturning stream functions. Ocean Dynamics, 64(6), 797-807.

Tjernström, M., Leck, C., Birch, C. E., Bottenheim, J. W., Brooks, B. J., Brooks, I. M., & Wheeler, C. R. (2014). The Arctic Summer Cloud Ocean Study (ASCOS): Overview and experimental design. Atmospheric Chemistry and Physics, 14(6), 2823-2869.

Turnewitsch, R., Falahat, S., Stehlikova, J., Oguri, K., Glud, R. N., Middelboe, M. & Yanagimoto, D. (2014). Recent sediment dynamics in hadal trenches: Evidence for the influence of higher-frequency (tidal, near-inertial) fluid dynamics. Deep Sea Research Part I: Oceanographic Research Papers, 90, 125-138.

Vihma, T., Pirazzini, R., Fer, I., Renfrew, I. A., Sedlar, J., Tjernström, M. & Gascard, J. C. (2014). Advances in understanding and parameterization of small-scale physical processes in the marine Arctic climate system: A review. Atmospheric Chemistry and Physics, 14(17), 9403-9450.

Walin, G., Hieronymus, J. & Nycander, J. (2014). Source-related variables for the description of the oceanic carbon system. Geochemistry Geophysics Geosystems, 15(9), 3675-3687.

Wesslén, C., Tjernström, M., Bromwich, D. H., de Boer, G., Ekman, A. M. L., Bai, L.-S., Wang, S.-H. (2014). The Arctic summer atmosphere: An evaluation of reanalyses using ASCOS data. Atmospheric Chemistry and Physics, 14(5), 2605-2624.

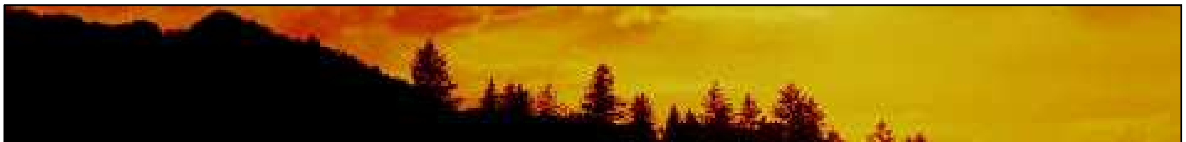
2015

Falahat, S. & Nycander, J. (2015). On the generation of bottom-trapped internal tides. Journal of Physical Oceanography, 45(2), 526-545.

Garcia-Carreras, L., Parker, D. J., Marsham, J. H., Rosenberg, P. D., Brooks, I. M., Lock, A. P. & Hobby, M. (2015). The turbulent structure and diurnal growth of the Saharan atmospheric boundary layer. Journal of Atmospheric Sciences, 72(2), 693-713.

Heifetz, E., Mak, J., Nycander, J. & Umurhan, O. M. (2015). Interacting vorticity waves as an instability mechanism for magnetohydrodynamic shear instabilities. Journal of Fluid Mechanics, 767, 199-225.

Huang, K., Yi, C., Wu, D., Zhou, T., Zhao, X., Blanford, W. J. & Li, Z. (2015). Tipping point of a conifer forest ecosystem under severe drought. Environmental Research Letters, 10, 024011.



STAFF

STAFF MEMBERS (AS OF DECEMBER 2014)

SCIENTISTS

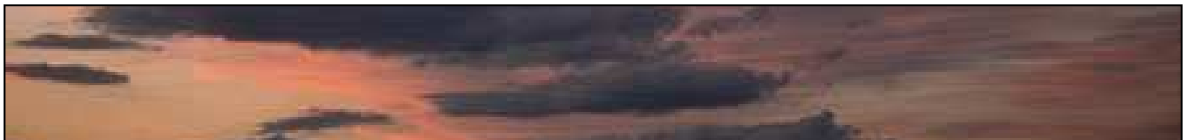
BENDER, Frida
BENZE, Susanne
BOURGEOIS, Quentin
BRODEAU, Laurent
CABALLERO, Rodrigo
CHIACCHIO, Marc
DÖÖS, Kristofer
EKMAN, Annica
GARCIA-CARRERAS, Luis
GRAND GRAVERSEN, Rune
GUMBEL, Jörg
HANNACHI, Abdel
HEDE, Thomas
HEDIN, Jonas
KARLSSON, Bodil
LECK, Caroline
LEJENÄS, Harald
LEWINSCHAL, Anna
LINDVALL, Jenny
LUNDBERG, Peter
LÖFVERSTRÖM, Marcus
MEGNER, Linda
MURPHY, Benjamin
NILSSON, Johan
NYCANDER, Jonas
MESSORI, Gabriele
PAUSATA, Francesco S.R.
PIERREHUMBERT, Raymond
RODHE, Henning (emeritus)
ROQUET, Fabien
SARDINA, Gaetano
SEDLAR, Joseph
SIGRAY, Peter
STEGMAN, Jacek
SVENSSON, Gunilla
VARMA, Vidya
TJERNSTRÖM, Michael

RESEARCH STUDENTS

ALDAMA CAMPINO, Aitor
BROOMÉ, Sara
CARLSON, Henrik
FRANSNER, Filippa
FREY, Lena
HAMACHER-Barth, Evelyne
HARTUNG, Kerstin
HENDRICKX, Koen
HIERONYMUS, Jenny
HULTGREN, Kristofer
HÖPNER, Friederike
IQBAL, Waheed
KAPSCH, Marie-Luise
LEUNG, WING
NYGREN, Eva
MASHAYEKHY, Farshid
PAUTHENET, Etienne
SALIH, Abubakr
SOTIROPOULOU, Georgia
STANEV, Marin
SVENSSON, Jacob
WOODS, Cian
XIANG-YU, Li
ÖDALEN, Malin

ADMINISTRATIVE AND TECHNICAL STAFF

BERGLUND, Susanna
BURGER, Mikael
DE HAAN, Albert
ERICSSON, Susanne
HALLENGREN, Göran
HAUSER, Solveig
IBANESCU, Iulia
KHAPLANOV, Mikhail
RÅBERGER T., Cecilia
SÖDERLUND, Jan
WALBERG, Nils
WALDAU, Anna-Karin
WESSLÈN, Cecilia
ÖHRSTRÖM, Agneta
ÖMAN, Åsa



VISITORS

VISITORS

DYNAMIC METEOROLOGY

Alexeev, Vladimir – *University of Alaska, USA*

Barnes, Elizabeth – *Colorado State University, USA*

Bintanja, Richard – *KNMI, The Netherlands*

Battisti, David – *University of Washington, USA*

Cristiansen, Bo – *DMI, Danmark*

Egger, Joseph – *Ludwig-Maximilians-University, Germany*

El-Feki, Amro – *King Abdulaziz University, Saudi-Arabia*

Frank, David – *WSL, Switserland*

Franzke, Christian – *Meteorological Institute of Hamburg*

Fu, Qiang – *University of Washington, USA*

Hess Peter – *Cornell University, USA*

Hirooka, Toshihiko – *Kyushu University, Japan*

Howell, Stephen – *University of Ottawa, Canada*

Jungclaus, Johann – *Max Planck Institute for Meteorology, Germany*

Khodri, Myriam – *Colombia University, USA*

Kruger, Kristin – *University of Oslo, Norge*

Källén, Erland – *ECMWF, UK*

Lee, Sukyoung – *Penn state University, USA*

Lui, Jiping – *Georgia Institute of Technology, USA*

Mahowald, Natalie – *Cornell University, USA*

Mahrt, Larry – *Oregon State University, USA*

McMurdie, Lynn – *University of Washington, USA*

Ming, Cia – *Florida State University, USA*

Mitchell, Jonathan – *UCLA, USA*

Noh, Yoo-Jeong – *Colorado State University, USA*

Ouali, Ammar – *Tunisian Met Office, Tunis*

Paldor, Nathan – *Hebrew University of Jerusalem, Israel*

Persson, Ola – *Cires, USA*

Risi, Camille – *CNRS, France*

Robock, Alan – *Rutgers University, USA*

Schmidt, Anja – *University of Leeds, UK*

Semedo, Alvaro – *Base Naval, Lisbon, Portugal*

Shupe, Matthew – *Cires, USA*

Sura, Philip – *Florida State University, USA*

Syed, Faisal Saeed – *Pakistan Met Office, Islamabad, Pakistan*

Timmreck, Claudia – *Max Planck Institute for Meteorology, Germany*

Trendafilov, Nickolay – *The Open University, UK*

Turner, Andrew – *Reading University, UK*

Zveryaev, Igor – *P.P. Shirshow Institute of Oceanography, Moscow, Ryssland*

PHYSICAL OCEANOGRAPHY

Barnier, Bernard – *University Joseph Fourier, France*

Biuw, Martin – *Akvaplan niva, Tromso, Norge*

Cuthbertson, Alan – *Hariot-Watt University, Edinburgh, UK*

Czaja, Arnaud – *Imperial College London, UK*

Dijkstra, Henk – *Utrecht University, The Netherlands*

Eden, Carsten – *University of Hamburg, Germany*

Ferreira, David – *MIT, USA*

Follows, Mick – *MIT, USA*

Griffies, Stephen – *Princeton University, USA*

Handler, Robert – *Texas A&M University, USA*

Jackson, Laura – *Mett Office, UK*

Jochum, Markus – *University of Copenhagen, Danmark*

Jönsson, Bror – *Princeton University, USA*

Laanearu, Janek – *Tallin Tech. Univ Tallin, Estland*

Laliberte, Frederic – *University of Toronto, Canada*

Legg, Sonya – *NOAA, USA*

Madec, Gurvan – *University of Southampton, UK*

Marchal, Oliver – *Woods Hole Oceanographic Institution, USA*

Nikurashin, Maxim – *University of Tasmania, Australia*

Nilsson, Jenny – *National Institute of Geophysics and Volcanology, Italy*

Oliver, Kevin – *University of Southampton, UK*

Pierrehumbert, Raymond – *University of Chicago, USA*

Restrepo, Juan Mario – *University of Arizona, USA*

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

Russell, Joellen – *University of Arizona, USA*

van Sebille Erik – *Imperial College London, UK*

Sobel, Adam – *Columbia University, USA*

Tedesco, Letizia – *University Finnish Environment Institute, Finland*

Tian, Yudong – *University of Maryland, USA*

Webber, Ben – *University East Anglia, UK*

Williams, Guy – *University of Tasmania, Australia*

Zika, Jan – *University of Southampton, UK*

CHEMICAL METEOROLOGY

Ayers, Greg – *Monash University, Australia*

Brooks, Barbara – *University of Leeds, UK*

Brooks, Ian – *University of Leeds, UK*

Budhavant, Krishnakant – *Maldives Climate Observatory, Republic of Maldives*

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

Chung, Chul Eddy – *GIST, Republic of Sought Korea*

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

Karl, Matthias – *Joint Research Centre, European Commission, Ispra, Italy*

L'Ecuyer, Tristian – *University Winconsin-Madison, USA*

Mauritsen, Thorsten – *Max Planck Inistitute for Meteorology, Germany*

McNeill, Faye – *Columbia University*

Moreno, Isabel – *University Mayor de San Andreas, Bolivia*

Ogren, John – *NOAA, USA*

Quaas, Johannes – *University of Leipzig, Germany*

ATMOSPHERIC PHYSICS

Bailey, Scott – *Virgina Tech, USA*

Baron, Philippe – *NICT, Japan*

Becker, Erich – *IAP, Germany*

Brakebusch, Matthias – *University of Colorado, USA*

Bourassa, Adam – *University of Saskatchewan, Canada*

Hervig, Mark – *GATS Incorporation, Driggs, Idaho, USA*

Hoffman, Anne – *Finnish Meteorological Institute, Helsinki, Finland*

Holt, Laura – *University of Colorado, USA*

Larsen, Miguel – *Clemson University, USA*

Lossow, Stefan – *Freie Universität Berlin, Germany*

Orsolini, Yvan – *Bjerknes Centre for Climate Research, Norge*

Sheese, Patrick – *University of Toronto, Canada*

Siskind, David – *NASA, USA*

Slanger, Tom – *SRI International, Menlo Park, California, USA*

Thomas, Gary – *University of Colorado, USA*

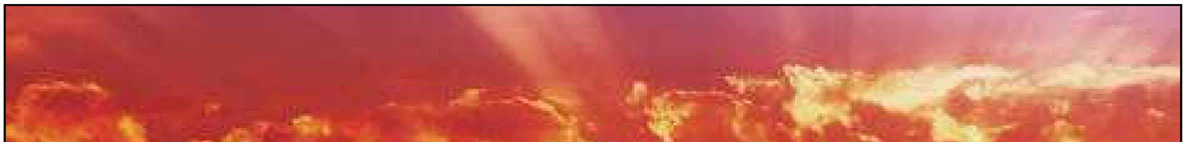
Von Savigny, Christian – *EMA University of Greifswald, Germany*

Yoshimura, Kei – *Department of Natural Environment Studies, Japan*

ROSSBY VISITING FELLOWS

Heifetz, Eyal – *Tel-Aviv University, Israël*

Noh, Yoo-Jeoug – *CIRA, USA*



FINANCES

FINANCES

	Approximate funding	MSEK
	2013	*2014*
International Meteorological Institute (IMI)		
Governmental support	*2.2*	*2.2*
Department of Meteorology, Stockholm University (MISU)		
Governmental support	*33.5*	*40.4*
IMI/MISU		
Additional external financial support	*22.6*	*23.8*

During the past two years the additional financial support has been obtained from:

European Space Agency

Swedish Environmental Protection Agency

European Commission

Foundation for Strategic Environmental Research (MISTRA)

Swedish National Space Board (Rymdstyrelsen)

The Swedish Research Council (VR)

The Swedish Research Council for Environment Agrcultural Sciences and Spatial Planning (FORMAS)

NORFA

Office of Naval Research (ONR)

STINT

Totalförsvarets Forsknings Institut (FOI)

The Knut and Alice Wallenberg Foundation (KAW)

United Nations Environment Programme (UNEP)

VINNOVA

Swedish Nuclear Fuel and Waste Management Co (SKB)

PHD THESES

PhD THESES 2013-2014

Peggy Achtert, 2003, Lidar Measurements of Polar Stratospheric Clouds in the Artic

Maxime Ballarotta, 2013, The thermohaline circulation during the Last Glacial Maximum and in the Present-Day climate

John Haley, 2013, Extreme Storms in the North Atlantic and Europa

Thomas Hede, 2013, Beyond Köhler Theory: Molecular dynamics simulations as a tool for atmospheric science

Sebastian Mårtensson, 2013, Ridged sea ice modelling in climate applications

Anna Lewinschal, 2013, Interactions between aerosols and large-scale circulation systems in the atmosphere

Raza Muhammad Ranjha, 2013, Global Climatology and Regional Modeling of Coastal Low-Level Jets

Leon Chafik, 2014, Dynamics and Variability of the Circulation in the North-Atlantic Subpolar Sea

Saeed Falahat, 2014, Tidally generated internal waves in the deep ocean

Kristofer Hultgren, 2014, Tomographic views of the middle atmosphere from a satellite platform

Jenny Hieronymus, 2014, The global marine carbon system through time

Magnus Hieronymus, 2014, An investigation into ocean thermodynamics and water-mass transformation

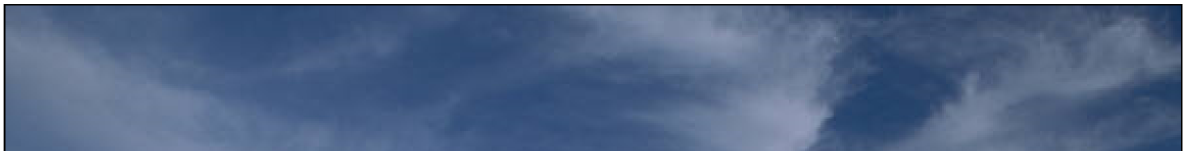
Joakim Kjellson, 2014, Atmospheric & Oceanic Applications of Eulerian and Lagrangian Transport Modelling

Jenny Lindvall, 2014, The representation of Atmospheric Boundery Layer Processes in Global Climate models

Marcus Löverström, 2014, On the interaction between ice sheets and the large-scale atmospheric circulation over the last glacial cycle

Jonas Mortin, 2014, On the Arctic Seasonal Cycle

Per Pemberton, 2014, Freshwater processes and water mass transportation in the Artic Ocean



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
ALOMAR	Arctic Lidar Observatory for Middle Atmosphere Research
AO	Arctic Oscillation
AOE	Arctic Ocean Expedition
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
CARMA	Commnity aerosol and radiation model för atmospheres
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
CW	Coastal Waves
DM	Dynamic Meteorology (a section of IMI/MISU)
DMPS	Differential mobility particle sizer
DMS	Dimethyl Sulfide
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
ECMWF	European Centre for Medium Range Weather Forecasts
ECOMA	Existence and Charge state Of Meteoric dust in the middle Atmosphere
EPS	Exopolymer Secretions
ERA	ECMF Re-Analysis
ESA	European Space Agency

EUFAR	European Fleet for Airborne Research
FSSP	Forward scattering spectrometer probe
GABLS	GEWEX Atmospheric Boundary Layer Study
GC	Gas Chromatograph
GCM	General Circulation Model
GEWEX	Global Energy and Water Cycle Experiment
HIRLAM	High Resolution Limited Area Model
ICSU	International Council of Science
IGBP	International Geosphere-Biosphere Programme
IITM	Indian Institue of Tropical Meteorology
IMI	The International Meteorological Institute in Stockholm
IN	Ice Nuclei
INDOEX	Indian Ocean Experiment
IPCC	Intergovernmental Panel on Climate Change
IPY	International Polar Year
ISAC	International Study of Arctic Change
ITM	Institute of Applied Environmental Research
LWC	Liquid Water Content
MAGIC	Mesospheric Aerosols □Genesis, Interaction and Composition
MBL	Marine Boundary Layer
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
NLC	NoctiLucent Clouds
NOAA	National Oceanic and Atmospheric Administration, USA
NRL	Naval Research Laboratory, Washington D.C.
OEM	Optimal Estimation Method
OPC	Optical Particle Counter
OSIRIS	Odin Spectrometer and InfraRed Imaging System
PRMIER	Process Exploration Measurements Infrared Emitted Radiation
PSAP	Particle Soot Absorption Photometer
RAPIDC	Regional Air Pollution in Developing Countries
RCA	Rossby Centre Atmospheric model
RCO	Rossby Center Ocean model
SAT	Surface Air Temperature
SEI	Stockholm Environment Institute
SHEBA	Surface Heat Budget of the Arctic Ocean

Sida	Swedish International Development Cooperation Authority
SLAM	Scattered Lyman-Alpha in the Mesophere
SMHI	Swedish Meteorological and Hydrological Institute
SMR	Sub-Millimetre Radiometer
SNSB	Swedish National Space Board
SST	Sea Surface Temperature
STEAM	Stratosphere-Troposphere Exchange And climate Monitor
SU	Stockholm university
SWECLIM	SWEdish regional CLImate Modelling programme
SWIFT	Stratospheric Wind Interferometer for Transport studies
TA	Transnational Access
TEM	Transmission electron microscopy
THC	ThermoHaline Circulation
TOA	Top of Atmosphere
TRACE	Transport and Chemical Evolution
UT/LS	Upper Troposphere/Lower Stratosphere
WCRP	World Climate Research Programme
WMO	World Meteorological Organization
ZAMM	Zeitschrift für Angewandte Mathematik und Mechanik