

# Dynamical meteorology

## 1996 - 2000

### 1. Summary of publications

Peer-reviewed	CC	Other	Monographs	Total	Abstracts
13	8	15	0	28	13/0

### 2. Overview

The Group of Dynamical Meteorology (DM) at Tartu Observatory (TO) was established in 1992 to promote the fundamental research into atmospheric dynamics and air pollution modelling in Estonia. The group has close cooperation with the Institute of Environmental Physics of the Tartu University, and participates in the MSc and PhD Curricula at the Institute.

#### 2.1 Principal research trends:

- Fundamentals of atmospheric dynamics in pressure-coordinate representation;
- Development and application of non-hydrostatic very high-resolution numerical weather forecast models;
- Numerical modelling of air pollution dynamics. Research into anthropogenic air pollution loads in Estonia and neighbouring Baltic Region.

#### 2.2 Personnel

**Head:** Rein Rõõm (55), Cand. Phys.-Math. Sci (PhD), Prof.

**Research staff:**

Marko Kaasik (34), PhD, postdoc research fellow

Aarne Männik (28), MSc, PhD student

**Junior research personnel:** undergraduate students

Andres Luhamaa (environmental physics),

Ivo Mägi (applied mathematics),

Tanel Lumiste (applied mathematics).

#### 2.3 Budget 1996 - 2000 (In kilo-EEKs)

Year	Target problems		Grants		R/D contracts		Infra-structure
	No	Budget	No	Budget	No	Budget	
1996	1	161	2	92.5	2	18	-
1997	1	235	1	80	3	31	-
1998	1	250	2	130	1	19	-
1999	1	330	2	153	1	6	-
2000	1	314	2	100	0	0	-

## **2. 4 Development headlines:**

1. The main strategic task is to develop further cooperation with the Department of Environmental Physics of Tartu University and to take more intensively part in the Curriculum of dynamical meteorology and environmental physics. At present there is a scenario under development according to which the Group of Dynamical Meteorology will join the University as the Chair of Meteorology.
2. Research headlines are: (1) continuing development of very high resolution forecast and climate models (new integration methods, new sub-grid parameterization schemes); (2) implementation of new forecasting software into practical use in Estonia; (3) research into planetary boundary layer physics for applications in numerical forecasting and air pollution models; (4) development of an integrated regional-scale air pollution dispersion and deposition model for Estonia.
3. More active participation in EC projects (including the Framework 5 programmes). Two joint projects on regional air pollution, and severe winter-condition weather event prediction are currently in application.

## **2. 5 Rooms and equipment**

Group has three rooms in good conditions in the main building of the Tartu Observatory including 7 workplaces.

The equipment consists of computing environment, which can be considered as "satisfactory" to "good":

Two PC workstations (700 and 500 MHz) installed under Linux;

Two PC workplaces under Windows;

Three relatively old (1993-1995) Silicon Graphics computers as terminals to workstations (courteous donation of the Finnish Meteorological Institute).

In addition, the Group has access to the Observatory's eight-node computer cluster and is one of its main loaders. Group has also access to the Finnish supercomputer Cray T3E, on which the most time-consuming numerical experimentation is carried out.

## **2. 6 Main scientific goals of the project: Climate Forming Factors and Dynamic Weather Forecast**

- Development of the theory of representation of nonhydrostatic atmospheric dynamics in pressure related coordinates, providing fundamentals for instant continuation of existing numerical weather forecast and climate models into the domain of nonhydrostatic resolutions.

- Development of numerical nonhydrostatic mesoscale models for simulations of atmospheric dynamics and weather forecast modelling.

- Development and application of regional-scale dynamic air pollution and deposition models.

## **2. 7 Main results:**

- Sigma-coordinate mesoscale model NHAD is developed (in collaboration with the Reading (UK) and Lisbon Universities). The model is main test tool for nonhydrostatic pressure-coordinate-based dynamics. The model will be applied for modelling of local coastal winds in the Baltic region.

- Nonhydrostatic kernel for the limited area weather forecasting model HIRLAM is developed and preliminarily tested. The kernel will be implemented in operational use as the core of a new-generation, very-high resolution forecast model at HIRLAM participating countries (Finland, Sweden, Norway, Denmark, The Netherlands, Ireland, Iceland, Spain, Lithuania, Latvia and Estonia).

- Air pollution dispersion and deposition models AEROPOL and AEROFOUR are developed and tested. Model AEROPOL is implemented in several environmental impact assessments and surveys in Estonia, and as a training model, and it is in implementation for evaluation of the environmental impact of large industrial energy, cement and chemical production sources in the north-eastern part of Estonia (in cooperation with Finnish Meteorological Institute and Institute of Ecology of Tallinn Pedagogical University). Model AEROFOUR will be implemented in the air pollution modelling system for Estonia (project proposal is submitted to the Estonian Centre of Environmental Investments).

## 2. 8 Peer-reviewed publications

### CC articles

1. **Rõõm R.:** Free and rigid boundary quasi-geostrophic models in pressure coordinates. *J. Atm. Sci.* 53, 1496 - 1501, 1996.
2. **Rõõm R.:** Acoustic filtering in non-hydrostatic pressure coordinate dynamics. A variational approach. *J. Atm. Sci.* 55, 134 - 149, 1998.
3. **Kaasik M., Liblik V., Kaasik H.:** Long-term Deposition Patterns of Airborne Wastes in the North-East of Estonia. *Oil Shale* 16, 315 - 329, and 1999.
4. **Rõõm R., Männik A.:** Response of Different High-Resolution, Nonhydrostatic, Pressure-Coordinate Models to Orographic Forcing. *J. Atm. Sci.* 56, 2553 - 2570, 1999.
5. **Rõõm R.:** Least Action Principle for General, Non-Hydrostatic, Compressible, Acoustically Non-Filtered Pressure-Coordinate Model. *Quart. J. Royal Meteorol. Soc.* 125, 1903 - 1907, 1999.
5. **Kaasik M., Rõõm R., Royset O., Vadset M., Sõukand Ü., Tõugu K., Kaasik H.:** Elemental and base anions deposition in the snow cover of North-Eastern Estonia. The impact of industrial emissions. *Water, Air, and Soil Pollution* 121, 349-366, 2000.
7. **Kaasik M.:** Validation of models AEROFOUR and AEROPOL using the model validation kit at Mol, *International Journal of Environment and Pollution* 14, 1-6, 160-166, 2000.
8. **Kaasik M., Sõukand Ü.:** Balance of alkaline and acidic pollution loads in the area affected by oil shale combustion. *Oil Shale* 17, 113-128, 2000.

### Other peer-reviewed papers

1. **Rõõm R., Ülejõe A.:** Nonhydrostatic acoustically filtered equations of atmospheric dynamics in pressure coordinates. *Proc. Estonian Acad. Sci. Phys. Math.* 45, 323 - 330, 1996.

2. **Kaasik M., Rõõm R.:** A Fourier-spectral model for air pollution dispersion calculations. Hurtalová, T. (editor), *Meteorological Processes in the Boundary Layer Of the Atmosphere*, Geophysical Institute of Slovak Academy of Sciences, Slovak Meteorological Society, Bratislava, 204-209, 1996.
3. **Kaasik M.:** Atmospheric Transport and Deposition of Technogenic Calcium: Model Estimation and Field Measurement. *Proc. Estonian Acad. Sci. Ecol.* 6, 41 - 51, 1996.
4. Gronskei K. E., Walker S. E., **Kaasik M.**, Kimmel V., **Rõõm R.:** Validation of local and regional air pollution models in northern winter conditions. *Air Pollution Modelling and its Application* 22, 737 - 738, Plenum Press, N.Y., 1998.
5. **Kaasik M.:** A model validation data set respect to the air pollution deposition in northern winter conditions. Gryning, S. E., Batchvarova, E. (Editors) *Air Pollution Modelling and its Application XIII*, Plenum Press, New York, 771-772, 2000.

### 3. Research grants

#### 3.1 Estonian Science Foundation grant 172(1993 – 1996)

#### **Nonhydrostatic Atmospheric Dynamics in Pressure-Related Coordinates**

**Grant holder:** R. Rõõm  
**Investigators:** R. Rõõm, A. Männik, P. Tisler, and A. Ülejõe  
**Total budget:** 182.5 kEEK

#### **Annotation:**

A comprehensive introduction to nonhydrostatic atmospheric dynamics in the unified pressure-coordinate framework is developed. Results of this investigation are further applied to the development of the model NHAD and nonhydrostatic kernel of HIRLAM.

#### **Peer-reviewed papers:**

1. **Rõõm R.:** Free and rigid boundary quasi-geostrophic models in pressure coordinates. *J. Atm. Sci.* 53, 1496 - 1501, 1996.
2. **Rõõm R., Ülejõe A.:** Nonhydrostatic acoustically filtered equations of atmospheric dynamics in Pressure coordinates. *Proc. Estonian Acad. Sci. Phys. Math.* 45, 323 - 330, 1996.
3. **Rõõm, R.:** Acoustic filtering in non-hydrostatic pressure coordinates dynamics. A variational approach. *J. Atm. Sci.* 55, 134 - 149, 1998.

#### 3.2 Estonian Science Foundation grant 186 (1993-1996)

#### **Air Pollution Modelling and Forecast**

**Grant holder:** R. Rõõm  
**Investigators:** R. Rõõm, M. Kaasik, student A. Nemvalts  
**Total budget:** 152.0 kEEK

#### **Annotation:**

Air pollution dispersion and deposition models AEROPOL and AEROFOUR are developed. Model AEROPOL is tested. Preliminary study of air pollution deposition

loads in the North-Eastern Estonian industrial region is carried out. Developed models are further implemented in several environmental impact assessments and surveys in Estonia, as training tools, and for evaluation of the environmental impact of large industrial energy, cement and chemical production sources of Estonia.

**Peer-reviewed papers:**

1. **Kaasik M.:** Atmospheric Transport and Deposition of Technogenic Calcium: Model Estimation and Field Measurement. *Proc. Estonian Acad. Sci. Ecol.* 6, 41 - 51, 1996.
2. **Kaasik M., Rõõm R.:** A Fourier-spectral model for air pollution dispersion calculations. Hurtalová, T. (editor), *Meteorological Processes in the Boundary Layer Of the Atmosphere*, Geophysical Institute of Slovak Academy of Sciences, Slovak Meteorological Society, Bratislava, 204-209, 1996.
3. Gronskei K. E., Walker S. E., **Kaasik M.**, Kimmel V., **Rõõm R.:** Validation of local and regional air pollution models in northern winter conditions. *Air Pollution Modeling and its Application* 22, 737 - 738, Plenum Press, N.Y., 1998.

*3.3 Estonian Science Foundation grant 3170 (1998-1999)*

**Regional Physiographic Database for Estonian Version of the Limited-Area Weather Forecast Model HIRLAM**

**Grant holder:** R. Rõõm  
**Investigators:** R. Rõõm, J. Roosaare, and M. Kaasik  
**Total budget:** 103.0 kEEK

**Annotation**

Physiographic database of the numerical weather forecast model HIRLAM is updated for the Eastern Baltic region to meet enhanced resolution requirements. The updated database is designed for implementation in the Estonian operational version of the HIRLAM.

Peer-reviewed papers: Nil; Other papers: two publications in the HIRLAM Newsletter, No 34 and 35.

*3.4 Estonian Science Foundation grant 2624 (1997-2000)*

**Dynamical Model for Simulation of Weather Processes in Estonia and Neighbouring Baltic Region**

**Grant holder:** R. Rõõm  
**Investigators:** R. Rõõm, A. Männik, M. Kaasik, undergraduates  
T. Lumiste, I. Mägi, A. Luhamaa  
**Total budget:** 397.7 kEEK

**Annotation**

The aim of the project is to develop the adiabatic kernel for a very high resolution, nonhydrostatic version of the limited area weather forecast model HIRLAM. The first version of the kernel, which makes use explicit-Eulerian integration scheme, is developed and preliminarily tested. The version with semi-implicit integration scheme

is under development. Model is aimed to implement as the new-generation, very-high-resolution operational forecast model in the HIRLAM participating countries, and to implement it as the research tool in the MSc-PhD Curricula at Tartu University.

#### **Peer-reviewed papers:**

1. **Rõõm R., Männik A.:** Response of Different High-Resolution, Nonhydrostatic, Pressure-Coordinate Models to Orographic Forcing. *J. Atm. Sci.* 56, 2553 - 2570, 1999.
2. **Rõõm R.:** Least Action Principle for General, Non-Hydrostatic, Compressible, Acoustically Non-Filtered Pressure-Coordinate Model. *Quart. J. Royal Meteorol. Soc.* 125, 1903 - 1907, 1999.

#### **4. Applications and R/D contracts**

4.1. Transfer of education-aimed software, 1996, 7000 EEK  
*Contract with Estonian Marine Education Center. Installing the AEROPOL model for teaching purposes.*

4.2. Upgrading and installation of the model AEROPOL, 1996 - 97, 18000 EEK  
*Contract with the Institute of Ecology (Estonia). Installing the AEROPOL model at the North-East Estonian Department of the Institute of Ecology. Development of user interface for AEROPOL. Reconstruction of the model for small-scale industrial applications: emissions from chemical tanks, transport, etc.*

4.3 Installation of the AEROPOL in Tallinn Technical University, 1997. 12000 EEK  
*Contract with Tallinn Technical University for installation of the AEROPOL model and configuration its database interface.*

4.4 Installation of the AEROPOL model and development of the database of air pollution sources for Tartu City, 1997 - 1999, 38000 EEK  
*Contract with Tartu City Government for introducing up-to-date information into database and development of the territorial database of air pollution emissions from industrial, transport and domestic heating sources.*

#### **7. Collaboration with other institutes and universities in Estonia**

Close collaboration exists with the Institute of Environmental Physics of Tartu University. The DM Group takes part in the Curriculum of environmental physics, including the MSc- and PhD -training. Group members deliver lecture courses of atmospheric dynamics, synoptic meteorology, boundary layer physics, and numerical methods in atmospheric physics. Head of the Group R. Rõõm is the visiting professor of dynamical meteorology (1998 - 2002) at the University.

Other domestic links exist with the Institute of Ecology of the Tallinn Pedagogical University (collaboration in air pollution problems) and Estonian Marine Institute (boundary layer wind modelling over sea).

#### **5. International cooperation**

Continuous collaboration (since 1994) is established with the Department of Meteorology of the Reading University (UK) and Department of Geophysics of the Lisbon University (Portugal). Essence of the collaboration has been the development of the nonhydrostatic, pressure-coordinate-based, anelastic mesomodel of atmospheric dynamics NHAD, suitable for high-resolution simulation of mesoscale events. The model is presently close to be finished. Since 1999, collaboration on regional air pollution modelling is initiated with the laboratory of Atmospheric Physics of the Aristotle University (Thessaloniki, Greece).

Close links exist with the research teams of the HIRLAM participants, where the Group is at present the basic developer of the nonhydrostatic kernel to the new-generation forecast model. Especially fruitful are the links with the Swedish Meteorological and Hydrological Institute, Finnish Meteorological Institute, and Department of Meteorology of the University of Helsinki.

#### Participation in international cooperation projects

Project	Partners	Source of financing	Budget
Quantification of alkaline and acidifying deposition loads from Estonian industry, 1999 - 2001.	Finnish Meteorological Institute, Tartu Environmental Research, Inc. (Estonia)	Nessling Foundation, Finland	220 000 FIM

### 9. Defended PhD and MSc Theses:

1. **P. Tisler** (1965), MSc, Tartu University, 1994: "The Quasi-geostrophic Model Of the Atmosphere. A Study of the Accuracy of Diagnostic Relationships", Supervisor R. Rõõm
2. **M. Kaasik** (1966), MSc, Tartu University, 1995: "Air Pollution Dispersion and Deposition Modelling in Local and Regional Scales", Supervisor R. Rõõm
3. **A. Ülejõe** (1970), MSc, Tartu University, 1996: "Non-Hydrostatic Pressure-Coordinate Models of Atmospheric Dynamics. Acoustic Noise Filtration Problem", Supervisor R. Rõõm
4. **A. Männik** (1972), MSc, Tartu University, 1997: "Water Transport and Phase Transitions in Numerical Meso-Models of the Atmosphere", Supervisor R. Rõõm
5. **M. Kaasik** (1966), PhD, Tartu University, 2000: "Parameterization of Atmospheric Boundary Layer in the Numerical Models of Air Pollution Transport", Supervisor R. Rõõm

### 10. Supervision of current PhD and MSc Theses

PhD Thesis "Semi-Implicit Integration Scheme for Anelastic, Nonhydrostatic, Pressure-Coordinate Model of Atmospheric Dynamics", A. Männik (1972), Supervisor R. Rõõm.

## 11. Curricula Vitae of principal investigators and grantholders

### 11. 1 Rein Rõõm: Curriculum Vitae

<b>1. Name</b>	Rein Rõõm
<b>2. Position</b>	Tartu Observatory, Head of the department of atmospheric physics and group of dynamical meteorology, senior research associate
<b>3. Date of birth</b>	October 17th, 1945
<b>4. Education</b>	Tartu University, Bachelor in physics, 1972
<b>5. Research and professional experience</b>	1972 -73 engineer at the IAAP (Institute of Astrophysics and Atmospheric Physics of the Estonian Academy of Sciences) 1973-83 Junior Research Associate at the IAAP 1983-89 Senior Research Associate at the IAAP 1989-95 Deputy director at the IAAP Since 1995 Head of the Department of Atmospheric Physics and Head of the Group of Dynamical Meteorology at TO (Tartu Observatory) 1983 -92 Lecturer, Chair of Geophysics, Tartu University (TU) 1993 - 97 Professor of Dynamical Meteorology, TU Since 1998 Visiting Professor at TU
<b>6. Professional training</b>	09.01 -31.03.1994 Reading University, England (TEMPUS) May 1995 University of Lisbon, Portugal (TEMPUS) December 1996 University of Munich, Germany (TEMPUS) February 1997 SMHI, Norrköping, Sweden (Research) 01.10.1998 -01.08.1999 Leverhulme fellow, Reading University, England (Research)
<b>7. Academic degree &amp; Thesis</b>	Candidate of Phys.-Math. Sci. (Ph.D.), 1981, Radiative Transfer in Planetary Atmospheres
<b>8. Research-administrative experience</b>	Chairman of the Estonian Committee for IUGG Member of American Meteorological Society and European Geophysical Society. Deputy Director of IAAP 1989-1995.
<b>9. Current research</b>	Numerical methods in atmospheric dynamics.
<b>10. Current grants</b>	ESF Grant 2624
<b>11. Dissertations supervised</b>	P. Tisler, MSc, Tartu University, 1994 M. Kaasik, MSc, Tartu University, 1995 A.Ülejõe, MSc, Tartu University, 1996



A. Männik, MSc, Tartu University, 1997

M. Kaasik, PhD, Tartu University, 2000

<b>Total number of peer-reviewed papers</b>	<b>1974 - 2000:</b>	<b>31</b>
<b>Other papers, including abstracts</b>	<b>1974 - 2000:</b>	<b>51</b>

### **Bibliography 1996 - 2000**

#### **Peer-reviewed papers:**

1. **Rõõm R.:** Free and rigid boundary quasi-geostrophic models in pressure coordinates. *J. Atm. Sci.* 53, 1496 - 1501, 1996.
2. **Rõõm R., Ülejõe A.:** Nonhydrostatic acoustically filtered equations of atmospheric dynamics in pressure coordinates. *Proc. Estonian Acad. Sci. Phys. Math.* 45, 323 - 330, 1996.
3. **Kaasik M., Rõõm R. :** A Fourier-spectral model for air pollution dispersion calculations. Hortalová, T. (editor), *Meteorological Processes in the Boundary Layer of the Atmosphere*, Geophysical Institute of Slovak Academy of Sciences, Slovak Meteorological Society, Bratislava, 204-209, 1996.
4. **Rõõm R., Kaasik M.:** Research into atmospheric dynamics at Tartu Observatory. *Proc. Estonian Acad. Sci. Phys. Math.* 45, 331 - 338, 1996.
5. **Rõõm R.:** Acoustic filtering in non-hydrostatic pressure coordinate dynamics. A variational approach. *J. Atm. Sci.* 55, 134 - 149, 1998.
6. Gronskei K. E., Walker S. E., **Kaasik M., Kimmel V., Rõõm, R.:** Validation of local and regional air pollution models in northern winter conditions. *Air Pollution Modeling and its Application*, 22, 737 - 738, Plenum Press, N.Y., 1998.
7. **Rõõm R., Männik A.:** Responses of Different High-Resolution, Nonhydrostatic, Pressure-Coordinate Models to Orographic Forcing. *J. Atm. Sci.* 56, 2553 - 2570, 1999.
8. **Rõõm R.:** Least Action Principle for General, Non-Hydrostatic, Compressible, Acoustically Non-Filtered Pressure-Coordinate Model. *Quart. J. Royal Meteorol. Soc.* 125, 1903 - 1907, 1999.
9. **Kaasik M., Rõõm R.,** Royset O., Vadset M., Sõukand Ü., Tõugu K., Kaasik H.: Elemental and base anions deposition in the snow cover of North-Eastern Estonia. The impact of industrial emissions. *Water, Air, and Soil Pollution* 121, 349-366, 2000.

#### **Other publications**

1. **Rõõm R. :** Nonhydrostatic atmospheric dynamics in pressure-related coordinates. *Grant of the Estonian Science Foundation No. 172, Final Report.* Tartu Observatory, 102 pp., 1997
2. **Kaasik M., Rõõm R.:** Air pollution modelling and forecast. *Grant of the Estonian Science Foundation No. 186, Final Report.* Tartu Observatory, 58 pp., 1997.
3. Rõõm, R.: Progress on development of a nonhydrostatic version of HIRLAM at Tartu Observatory. *Hirlam Newsletter*, No. 31, 44 - 45, 1998.
4. **Rõõm R.:** Nonhydrostatic formulation of the HIRLAM. <ftp://apollo.aai.ee/pub/nhlect.ps> 23 pp. , 1998.
5. **Rõõm R., Männik A.:** Nonhydrostatic adiabatic kernel for HIRLAM. In: *HIRLAM Newsletter*, No. 35, 103 - 109, and 2000.
6. **Männik A., Rõõm R.:** Nonhydrostatic adiabatic kernel for HIRLAM. Part II. Anelastic, hybrid-coordinate, explicit-Eulerian model:

<http://apollo.aai.ee/HIRLAM/nhkern2.ps>, 60pp., 2000.

7. **Rõõm R.:** Nonhydrostatic adiabatic kernel for HIRLAM. Part I. Fundamentals of nonhydrostatic dynamics in pressure-related coordinates: <http://apollo.aai.ee/HIRLAM/nhkern1.ps>, 23pp., 2000.

+ 9 conference papers and abstracts

### **Participation in scientific meetings 1996 - 2000**

XXVI Estonian Physics Days (Tartu, Estonia, 03-04.02.1996)

Kaasik M., **Rõõm R.:** Air pollution dispersion models.

**Rõõm R.:** Wave filtration problem in atmospheric dynamics.

World Congress of Estonian Scientists (11. - 15.08.1996, Tallinn)

**Rõõm R.,** Kaasik M.: On the atmospheric dynamics research in Tartu Observatory.

EGS XXII General Assembly (Vienna, 21.04.-25.04.1997) .

**Rõõm R.,** Lindmaa Ü., Männik A.: Response of different acoustically filtered high-resolution pressure-coordinate models to orographic forcing.

HIRLAM Workshop on High Resolution Modeling (Norrköping, Sweden, 10.05.-12.05.1999) .

**Rõõm R.:** On the Development of a Nonhydrostatic Version of HIRLAM.

XXII General Assembly of the International Union of Geodesy and Geophysics (Birmingham, United Kingdom, 19.07.- 24.07.1999)

Männik A., **Rõõm R.:** Orographic Waves in Pressure-Coordinate Dynamics.

Seminar of the Estonian Academy of Sciences "Science to the Society", (Tallinn, 03.12.1999).

**Rõõm R.:** Perspectives of Numerical Weather Forecast for the World, Europe, and Estonia.

HIRLAM Annual Meeting (Norrköping, Sweden, 27.03.-29.03.2000)

**Rõõm R.:** Nonhydrostatic adiabatic kernel for HIRLAM.

IUTAMLIM (International Union of Theoretical and Applied Mathematics) Symposium "Advances in Mathematical Modelling of Atmosphere and Ocean Dynamics" (University of Limerick, Limerick, Ireland, 2.07.-7.07.2000)

**Rõõm R.:** Acoustic filtration in pressure-coordinate models. Basic concepts and applications in nonhydrostatic modelling.

## **12. Curricula Vitae of the principal investigators**

### **12.1 Marko Kaasik: Curriculum Vitae**

**Name** Marko Kaasik

**Date of birth** July 25, 1966  
**Academic degree** PhD in environmental physics, Tartu University, 2000  
**Position** Research Fellow/Postdoc  
**Research training** 1996 - in Norwegian Institute for Air Research (granted by Norwegian Research Council);  
1997 - in the University of Reading, UK (granted by TEMPUS).  
**Research activities:** Air pollution modelling and model validation (incl. field campaigns);  
**Lecturing :** 1996 - course "Numerical methods in Meteorology" at Tartu University;  
1998 –1999 - course "Atmospheric hygiene and air pollution transport" at the Türi College of Tartu University;

**Number of peer-reviewed publications: 8 (incl. 4 CC)**

## **12. 2 Aarne Männik: Curriculum Vitae**

**Name** Aarne Männik  
**Date of birth** 1972  
**Academic degree** MSc in environmental physics, Tartu University, 1997  
**Position** PhD student at the Institute of Environmental Physics, Tartu University  
**Research training** 08.01-07.02.1996: European Research Course on Atmospheres in Grenoble, France  
October 1998: HIRLAM training workshop in Riga, Latvia  
**Research activities** Mathematical and physical problems in nonhydrostatic modelling of atmospheric dynamics  
**Stipends** 1999 - 2001: Väisälä Foundation Stipend from Finnish Academy of Sciences  
**Lecturing** 1998 - 2000: Course "Numerical models of the atmosphere" at Tartu University.

**Number of peer-reviewed papers: 2**