

Knowledge for Climate (KvK)

Research Proposal

revised June 2009

Hotspot Mainport Schiphol

1. Registration details

◆ Project ID:	HSMS03 (modification of previous research proposal)
◆ Submission date:	12-06-2009
◆ Title:	"The impact of climate change on the critical weather conditions at Schiphol airport" (Impact)
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◆ Research location:	De Bilt
◆ Duration of the requested subsidy:	24 months
◆ Type of research:	<input type="checkbox"/> fundamental research <input checked="" type="checkbox"/> applied research <input type="checkbox"/> experimental development (demonstration project) <input type="checkbox"/> definition project (exploration project) <input type="checkbox"/> communication project

2. General research characteristics

◆ Abstract (max. 200 words):	<p>The aim of this project is:</p> <p><i>"To quantify and better understand the impact of climate change on the critical weather conditions at Schiphol airport, by using the state-of-the-art high-resolution atmosphere model HARMONIE"</i></p> <p>Schiphol operation is very sensitive to critical weather conditions. An important question for Schiphol is how to maintain a sustainable and reliable airport operation when in a future climate the frequency and intensity of critical weather conditions will change. In order to answer this question, we need to determine these changes with sufficient accuracy. Present day climate models are not suited for that. Their grid resolution is too coarse. In this project we will explore the use of the newly developed atmospheric model HARMONIE to compute these changes on local scales, and to better understand why these changes occur. The results of this project will contribute to increase the amount</p>
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of spatial detail in the KNMI'06 climate scenarios for the Netherlands, especially those details that are related to a proper description of the land-atmosphere interaction in the climate system.

In this project we will build up a strong knowledge base at all partner sites and use this knowledge base to demonstrate the potential of HARMONIE to carry out future climate case-studies for Schiphol airport. The results will be demonstrated to the airport stakeholders.

◆ **Research topic:**

The main research topics of this project are:

- 1) Set up of an “academic” version of the high-resolution 3D HARMONIE model, delivering basic weather information on wind, precipitation and clouds on spatial scales of 1–2 km for Schiphol airport, to be used for climate research. The academic version will be locally implemented at Wageningen and Delft University with the aim to enlarge the research capacity within this project and beyond;
- 2) Implementation of the additional 1D COBEL model which will be nested in HARMONIE and used to provide specific weather information on fog and low clouds for Schiphol airport;
- 3) Development of an interface that can be used to run HARMONIE in a future climate, i.e. with large scale boundary conditions provided by a (regional) climate model (RACMO);
- 4) Performing case studies that show the potential of HARMONIE and COBEL to compute changes in critical weather conditions at Schiphol airport due to climate change;
- 5) Set up an evaluation environment for HARMONIE and COBEL;
- 6) Specification of weather parameters and their safety thresholds that affect the operation at Schiphol airport in a future climate;

◆ **Problem definition:**

1. The requirements of Schiphol

Schiphol operation is most sensitive to critical weather conditions, and sudden changes in these. The following parameters are relevant:

- Wind direction, wind intensity and wind fluctuations (gusts),
- Precipitation intensity and type (snow, hail, (freezing) rain, rime),
- Low visibility (fog) and low clouds,
- Weather events which are especially dangerous for Schiphol operation: severe thunderstorm and lightning, downbursts,
- Surface and upper-air temperature;

Due to its location near the sea, Schiphol weather is often adverse and subject to sudden changes. Critical weather conditions, like fog, stormy winds and heavy precipitation, lead to a loss in the available airport capacity, and if not foreseen in time, to additional delays, diversions and holdings, resulting in increasing costs. To increase safety and guarantee operational efficiency during flight operation, accurate and reliable information on critical weather parameters and their changes on local scales is needed. This will be even more pressing when in a future climate adverse weather occurs more often, is more intense and is due to more sudden changes. For the application of weather forecasts at the airport, “safety” thresholds are defined for weather parameters such as wind and visibility. Weather forecasting models must be able to forecast these thresholds with adequate accuracy.

Wind

For safety and efficiency, airplanes should maximize their possibility to land and take-off against the wind. This is not always possible due to the existing runway orientation and sudden wind variations. In practice, airplanes often operate under crosswind and sometimes tailwind conditions. For safety, cross- and tailwind values are restricted to certain limits. Depending on the condition of the runway, these limits are 20 kts for crosswind and 7 kts for tailwind. Sudden fluctuations in

the wind (gusts) of 10 kts and more should be included in the total wind intensity. When crosswind limits are exceeded and there are less runways available which are parallel to the wind, this will lead to a loss of available operational airport capacity. This happens for example during strong southwesterly winds. To reduce the adverse effect of wind and wind change on operations, accurate forecasts are needed for periods when cross- and tailwind components exceed their limits near touch-down and take-off positions at the runways.

Visibility and low clouds

Adverse visibility conditions have a direct negative influence on the available operational capacity. For example, at Schiphol airport the number of arrivals and departures reduces by a factor 2 when visibility is less than 600 m or when cloud ceiling is less than 200 ft. Accurate information on the time of onset and cessation of these conditions will allow for a more efficient use of the available airport capacity. This requires accurate forecasts of visibility and low clouds, of their spatial variability and temporal fluctuations at the airport.

2. The problem of Schiphol caused by climate change

The impact of climate change on Schiphol Mainport is determined by the effect that the future weather will have on the airport operation. The main problem is that we do not know how climate change affects the critical weather conditions at the airport. Specific questions related to the Schiphol situation are:

- How will local precipitation extremes at Schiphol airport change when air temperature and sea-surface temperature increase in a future climate?
- How will changes of our climate, of the physiographic properties of the landscape (such as land-use, vegetation and soil type), or of spatial planning, affect the local weather conditions at the airport for wind, low clouds and fog?

The KNMI'06 climate scenarios (*Bart van den Hurk et al. 2006*) show that the intensity of extreme rain showers in summer will increase. But, it is still poorly understood how short-duration convective showers will grow due to temperature increase, and our abilities to model rainfall processes in climate models is limited (*Lenderink et al. 2008*).

The typical grid resolution in our state-of-the-art global and regional climate models is still too coarse to examine the effects of the local topography and land-use, and to quantify local extreme events. In this project the use of a new, non-hydrostatic, weather model is proposed to physically downscale large scale climate conditions to generate local weather parameters with higher temporal and spatial variability.

To guarantee a sustainable and reliable operation of Schiphol airport in a future climate, changes in the frequency and intensity at which local weather conditions that are critical for Schiphol will occur, should be identified and quantified. Scientists and several users of aviation weather forecasts, such as Schiphol authorities, Air Traffic Control and KLM airlines, are questioning the ability of our present day climate models, to determine with sufficient accuracy changes of critical weather conditions at Schiphol airport, caused by climate change.

Surface weather variables, boundary layer structures, wind, clouds and precipitation, are substantially driven by local physiographic properties and by the heterogeneity of the landscape. Our models display relative poor skills to compute these variables, especially in critical situations when the weather is often very intense and the spatial and temporal scales of the weather structures are small (mesoscale). The most important reasons are:

- a) Present day climate models are hydrostatic and have a coarse resolution. This is also true for our current operational weather prediction model which has a grid resolution of 10–20 km. The hydrostatic assumption and coarse resolution are insufficient to numerically resolve most of the key physical processes that lead to critical local weather conditions such as convective showers, local winds, and the formation and decay of fog and low clouds.
- b) The description of the physical land-surface and boundary layer processes associated with for example fog and low clouds (e.g. the interaction between turbulence, radiation and microphysics) is poor in the models.
- c) A local high-resolution observing network is missing. Such a network provides detailed measurements of the state of the surface layer. These measurements are needed to construct a high-resolution model field analysis, but also for model validation. Furthermore these measurements can be used to compute an accurate initial state in a weather prediction model.

3. The solution for Schiphol

To be able to compute the effect of climate change on the critical weather conditions at Schiphol airport with sufficient accuracy, we need a weather analysis and prediction model with a spatial resolution of 1 – 2 km. Numerical weather prediction (NWP) at such a high resolution requires a complete metamorphosis of the model on:

- 1) Model dynamics,
- 2) Model physics,
- 3) Model analysis;

During the last 10 years, intensive research has brought increased knowledge on model dynamics, model physics and model analysis. A non-hydrostatic treatment of model dynamics enables us to explicitly resolve vertical (convective) movements in the model (*Kato 1997*). This is necessary for explicit simulation of small-scale clouds. A consistent treatment of sub-model-grid processes has led to a unified approach for the physical parameterisation of clouds, turbulence and convection in the atmospheric boundary layer of the model (*Siebesma et al. 2007, Neggers et al. 2008*). New generation observing systems such as the Meteosat and Metop satellites (www.eumetsat.de) and high quality wind profiles from Doppler weather radars (*Holleman 2005*) enable us to observe the state of the atmosphere with much higher spatial and temporal resolution. New data assimilation techniques are presently being developed that enable us to incorporate these observations in NWP models, with the purpose to improve the analysis of our model fields (*Brousseau et al. 2007*). Furthermore, these measurements can be used for model validation.

The newly achieved knowledge is presently being implemented by a large European consortium (*the “HiRLAM-ALADIN collaboration”*), in the next generation non-hydrostatic NWP model, called **HARMONIE** (see www.hirlam.org).

In this research we will show the potential of the mesoscale model HARMONIE to determine changes of the critical weather conditions at Schiphol airport as a consequence of climate change.

The use of HARMONIE within this context has several advantages:

1. HARMONIE will be the next generation weather analysis and forecasting model, and will be used operationally by a large number of European national meteorological services;
2. HARMONIE contains a data assimilation module that can be used to incorporate observations and compute analysed model fields, which are suited for the monitoring of weather and climate

related variables;

3. The HARMONIE consortium will take care that the model can be used under various circumstances and for extreme weather conditions. The model will be supplied with a quality label;
4. The ECMWF (European Centre for Medium-Range Weather Forecasts) will develop a non-hydrostatic forecast model along the same lines as HARMONIE;
5. HARMONIE and ECEARTH both use as system environment IFS (Integrated Forecast System), which enables a future integration of both models in the KKF;

◆ **Research objective(s):**

The main research objectives are:

1. To provide an inventory of critical weather parameters that impact the airport operation at Schiphol;
2. To provide an “academic” version of the 3D HARMONIE model to be implemented and used at KNMI and various Dutch universities for climate research on basic high-resolution weather parameters for Schiphol airport;
3. Mutual knowledge transfer so that universities get interested to focus and apply their research efforts to Schiphol airport as well;
4. To provide the 1D COBEL model, embed it in HARMONIE, and use it to produce specific weather parameters for fog and low clouds at Schiphol airport;
5. Coupling of HARMONIE to large scale, future climate, boundary conditions provided by a (regional) climate model (RACMO);
6. Apply HARMONIE and COBEL for several “future weather” case studies, with focus on convective precipitation, dense fog and fast changes in wind speed and wind direction. Show the potential of HARMONIE to compute changes in critical weather conditions at Schiphol airport caused by climate change;
7. Validate HARMONIE and COBEL with local observations at the airport;

Ad 1.:

We will provide an overview of local weather parameters that impact the airport operation, their order of relevance and the corresponding “safety” thresholds. This inventory will help us to better understand the needs of Schiphol operations for weather information. Some weather parameters are not provided directly by our models. The inventory should give more insight in which parameters to retrieve from our models and how they should be further post processed to derive the required information.

Ad 2. and 3.:

In the research and development of HARMONIE mainly the national meteorological institutes in Europe are involved. The available research capacity is therefore limited but could be increased by the involvement of universities that are engaged in atmospheric research as well. In collaboration with the HiRLAM/ALADIN consortium, we will set up an “academic” version of HARMONIE that can be used for research at universities. This academic version will contain the model components that are necessary to study local weather processes at Schiphol airport, and elsewhere in the Netherlands, but will not be suitable for operational weather forecasting. Knowledge transfer between the HiRLAM/ALADIN consortium and universities is also needed for an efficient use of HARMONIE for research purposes (e.g. Schiphol case studies). In this context it is worthwhile to mention that the 2009 HiRLAM/ALADIN conference will be held in Utrecht (12-15 May 2009), and provides a low threshold for Dutch researchers to get close contact with the HiRLAM/ALADIN community. The increased research capacity is a key precondition for the success of this project.

Ad 4.

A model like HARMONIE tries to overcome some of the deficiencies of our present climate models. However, quite a few of these, especially those related to the computation of local phenomena such as fog, will not be taken away by HARMONIE. It is for this reason that for fog and low clouds we propose an inherently different approach based on using a one-dimensional column model. This model, called **COBEL**, has been developed by a French research consortium. At present it is successfully being used as an operational prediction tool for fog and low clouds at the international airport Paris Charles de Gaulle where it has been shown to be a superior short-term forecasting tool of fog and low cloud conditions up to 6 hour ahead (*Bergot et al. 2005*). COBEL will be used in this project to post process basic HARMONIE model parameters to specific weather parameters for fog and low clouds.

Ad 5.:

The HARMONIE model will be used in this project to determine the local implications of climate change on the weather conditions at the airport. In order to run HARMONIE in a future climate, large scale boundary conditions, such as wind and temperature at the upper boundary and sea-surface temperature at the lower boundary, are needed. These will be provided by a (regional) climate model (RACMO). A coupling interface will be provided to enable HARMONIE to use these boundary conditions. In this approach, HARMONIE will be used to downscale large scale climate predictions to a local scale at Schiphol airport.

Ad 6. and 7.:

We will carry out a show-case to demonstrate the applicability of HARMONIE to compute small-scale future weather conditions. The HARMONIE results will be compared to the coarse model results from the (regional) climate model. A similar case in our present climate will be carried out to identify the skill of the mesoscale model under similar circumstances. For model validation, local airport observations, such as high precision measurements of 3D wind fields, wind fluctuations and visibility (provided by the project "WindVisions"), will be used. The potential of HARMONIE to compute changes in critical "future weather" conditions for Schiphol airport will be shown to the stakeholders.

3. Scientific aspects

◆ Central research questions and sub-questions:

As mentioned in the previous section, the main objective of this proposal is to determine, with sufficient skill, changes in the critical weather conditions at Schiphol airport such as caused by climate change. To this purpose it is proposed to implement, apply and evaluate two new model tools:

- 1) The high-resolution 3D weather prediction model HARMONIE that will operate at a unprecedented high horizontal resolution of 2.5 km,
- 2) The special purpose 1D column model COBEL-ISBA that is specifically designed to produce additional weather parameters for fog and low clouds, and is suited to make short-range forecasts on time scales of 0 to 6 hrs ahead;

There are 4 central research questions in this project:

- *How is the performance of the new model tools for critical weather parameters that are relevant for the operations at Schiphol airport?*
- *What changes in critical weather parameters at Schiphol airport will these model tools show in the light of climate change?*
- *Which components in the data assimilation as well as in the model formulation play a crucial role in producing a high quality field analysis for the Schiphol area and how can we improve these?*

The fourth question is especially related to COBEL-ISBA. Since this 1D column model post-processes on basic weather parameters from HARMONIE, an accurate initialisation of the column, either by model parameters from HARMONIE or by observations, is crucial: A critical issue in this respect is:

- *What is the optimal set of simulated observations from HARMONIE, or observational instruments at Schiphol airport, to have an optimal guess of the initial state and to validate the column model?*

Regarding the *first question*, a number of documented cases will be hindcasted and evaluated on relevant weather parameters: wind, precipitation, visibility and cloud base height. These cases will consist of a representative number of past weather situations that have caused serious disruption in the operations of Schiphol airport. These include situations with: storm conditions, squall lines, deep convective cells, heavy precipitation, fog and low clouds. As the COBEL-ISBA model is a special purpose model for fog and low clouds, its performance will be evaluated for cases based on these weather conditions only.

Regarding the *second question*, case studies will be performed with large scale boundary conditions provided by a (regional) climate model. Here we will focus on cases with heavy precipitation, strong winds, and fog and low clouds.

Regarding the *third question*, sensitivity studies will be performed with model parameters that are uncertain and affect the analysed model fields for the weather situations mentioned above.

Regarding the *fourth question*, COBEL-ISBA will be operated at the KNMI Cabauw international measurement site at which a large suite of observational instruments is available. This allows us to directly validate COBEL-ISBA at Cabauw, and to decide which observations, or simulated observations from model data, are necessary to initialise the 1D column model at Schiphol airport. Since radiative cooling plays a crucial role in fog formation, COBEL will also be evaluated for its ability to reproduce radiative flux divergence using an existing dataset at the Wageningen meteo-station (*Steenveld et al. 2008a*).

◆ **Scientific relevance and innovative value:**

Both proposed model structures are new innovative tools that have high potential for substantial increase in the skill to compute climate projections on local scales and with extreme intensity. If correctly driven by larger scale climate models they can be used as dynamical downscaling tools to provide local weather statistics in a future climate. This will be further demonstrated for HARMONIE and COBEL-ISBA below:

HARMONIE

In principle HARMONIE is much better equipped than the current climate and weather prediction models to describe the meteorological conditions in the Schiphol area on small spatial and temporal scales. With the non-hydrostatic model HARMONIE it is possible to test the latest ideas on physical processes at a grid resolution which is adequate for describing meteorological features like convective showers and strong gradients in local wind. The available model infrastructure provides a possibility to easily compare different physics modules in HARMONIE as well as in the future the opportunity to explore the potential of a high density observing network for model field analysis and model validation.

At this stage HARMONIE runs at various European meteorological services in a pre-operational suite and there is much interest at these services to improve the quality of the HARMONIE forecasts. This

project can share in this development and contribute to it, e.g. by acting as a focal point for relevant meteorological knowledge on critical weather parameters at airports and their changes caused by climate change.

With the advent of high-resolution models like HARMONIE small-scale phenomena, such as the location of a squall line, can be resolved properly for the first time. The predictability of such features will be a challenge for the coming years and sensitivity experiments carried out with HARMONIE will provide valuable knowledge in this new research direction.

COBEL-ISBA

The development of a local site-specific model meets the urgent needs of the aviation community to derive high quality model parameters for fog and low clouds at airports. The use of single-column models for this purpose is also a key-topic at French airports such as Paris – Roissy and Paris – Charles de Gaulle where it has shown to be an improvement over other more traditional methods.

Besides more details in specific model parameters for fog and low clouds, the single-column model is also an engineering tool that can be used to increase understanding of atmospheric processes related to fog and low clouds (e.g. microphysics), and of the impact of the initial conditions of the column and the external mesoscale flow thereon.

Furthermore, the column model can be used to explore the potential of high-resolution atmospheric boundary layer measurements for initialising numerical weather prediction models in general.

The model can run in an Eulerian framework over different locations, or in a Lagrangian framework in cases of advection of fog. Due to its low computational costs, we can run the model with a high-frequency update cycle or/and in an ensemble mode which allows us to make different model scenarios. Fog and low clouds are small-scale phenomena that are sensitive to initial conditions and the mesoscale flow. This provides a possibility to use the single-column model for the development of a local ensemble prediction system and derive probability forecasts to users, which is a relative new research area.

◆ Research approach and methodology:

1 The three- dimensional model HARMONIE

1.1 Introduction

Since the HARMONIE development at meteorological services aims at an operational use, several adaptations have to be made in order to enable use for climate research at universities. Here we propose to set up a knowledge base which will be equipped with an academic version of the HARMONIE weather prediction model that easily can be used by researchers at KNMI and various Dutch universities (for example Delft and Wageningen University, and IMAU/University of Utrecht) to facilitate climate research such as model analysis, monitoring and local climate studies at Schiphol airport and elsewhere.

1.2. Requirements for an academic version of HARMONIE

For the academic version of HARMONIE several requirements are formulated, which should, when fulfilled, enable researchers involved in this project to implement locally an easy to use state-of-the-art high-resolution atmospheric model and to get acquainted with HARMONIE software. To meet the requirements the following tasks should be completed:

- i) Arrange a license agreement (permission) for academic use of the HARMONIE software on a standalone platform.

- ii) Set-up of a website that provides a download link to a version of HARMONIE, a list of supported platforms (hardware, operating systems, compiler) and performance information.
- iii) Formulate instructions how to make, built and install a default version of HARMONIE.
- iv) Provide input data for selected meteorological cases, together with forecast data, which can also be used as a sanity check for the model installation.
- v) Provide documentation on the default HARMONIE version (physics, climate, nesting setup). The documentation should also provide guidance on how to modify source code or how to alter important model options, e.g. to run with different boundary conditions such as SST.
- vi) Define a user friendly interface to run the model (e.g. prepIFS as is used to submit IFS experiments) and to navigate through the source code.
- vii) Provide diagnostic tools to post-process and to visualize the model data (preferably by using open source software)
- viii) Enable use of relevant input datasets, e.g. by providing conversion tools for NetCDF.
- ix) Install a Helpdesk for model users and developers, provide access to a FAQ database, a communication platform etc..

1.3. Exploration and improvement of HARMONIE

The development of HARMONIE is an ongoing HIRLAM/ALADIN activity and it is likely that during this project updates of physics packages or additional model components become available, e.g. an improved formulation of convection. Implementation of these new model components into the academic version will be done when appropriate, and after approval for academic use has been granted.

During the process of defining an academic version of HARMONIE, it is foreseen that properties of HARMONIE that are related to critical weather conditions at Schiphol airport will be evaluated thoroughly by the project partners. In particular its performance for Schiphol airport will be validated against local observations and by studying several cases. Areas where additional research is anticipated in order to optimize HARMONIE's usefulness for Schiphol airport are:

- i) Identification of meteorological situations, which pose difficulties for HARMONIE. For example, the occurrence of too strong outflows during cases of heavy convective precipitation (so-called fire works). A detailed investigation of selected test cases will be performed and possible influence of the horizontal diffusion and the sub-grid turbulence and convection parameterizations will be explored. Another issue which needs attention is the proper representation of the diurnal cycle in HARMONIE over various terrain conditions in the Netherlands. As such novel observations in a Dutch network of scintillometers and ceilometers (e.g. from "WindVisions") will be used (e.g. *Steenefeld et al. 2008b*).
- ii) Sensitivity experiments with HARMONIE. For example, the impact of grid resolution and model boundaries on model performance. In particular, the conditions under which triggering of convection takes place in a non-hydrostatic model in relation to varying spatial resolution will be studied, as well as the representation of the stable boundary layer (e.g. *Steenefeld et al. 2008c*).

2 Site-specific one-dimensional Column model COBEL-ISBA

2.1 Introduction

Single column models (SCM's) such as COBEL-ISBA (see figure 1) are capable to derive specific model parameters for fog and low clouds

when these are predominantly driven by local influences that are poorly forecasted by operational NWP models. Our starting point will be to use the French single column model COBEL-ISBA (COBEL = Code de Brouillard a l'Echelle Locale, ISBA = Interaction Sol Biosphere Atmosphere) which is already operationally used at several French airports. Intercomparison studies between different SCM's in the context of a COST action (*Jacobs et al., 2005*) also showed a superior short term predictive skill behaviour of this model when intercompared with other SCM's.

The French National weather service Meteo France (MF) is willing to provide the software and to support the installation and implementation of the model for use at locations of interest in the Netherlands. A license agreement (permission) for use of the model is needed for this.

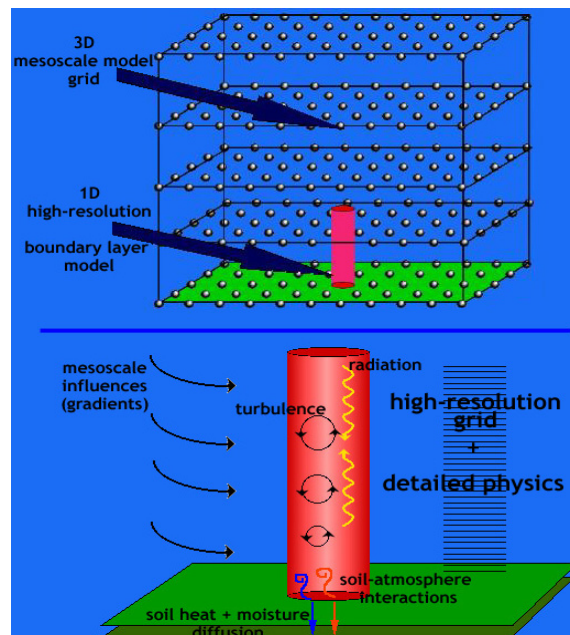


Figure 1: High-resolution 1D column model (nested in 3D model for external forcing).

The COBEL model can run at an arbitrary high (vertical) resolution, for example 20 levels in the lowest 200 m. The model physics of COBEL includes: i) a turbulent kinetic energy (TKE) scheme for the turbulent mixing in the boundary layer, ii) a prognostic equation for the condensed liquid water that includes condensation, turbulent transport and gravitational settling of the cloud droplets, and iii) an advanced longwave radiation scheme using 232 spectral intervals. The atmospheric component of the model is coupled with a multilayer surface-vegetation-atmosphere scheme in which 7 layers are used to represent a soil column of 2 m depth. The model equations are derived under the assumption of horizontal homogeneity. However, spatial heterogeneities are treated as external forcing terms which can be provided by a NWP model such as HARMONIE. The column model can be initialised with local observations. For the initial state of the temperature and humidity profiles a one-dimensional variational framework is used. An accurate estimate of the initial state is crucial. For this purpose tower measurements are needed for temperature and humidity as well as in the soil, radiative flux measurements at two vertical levels and direct observations of fog and low clouds. In case observational data for initialisation of the model is missing, for example when applying the model to derive future climate predictions, these observations should be simulated with model data.

2.2 Implementation and evaluation of COBEL-ISBA

As a first step COBEL-ISBA will be implemented at 3 locations: Schiphol, Wageningen meteo-station (Steenefeld et al. 2008a) and Cabauw which is an international observation site (see van Ulden and Wieringa 1996). In this first stage external forcing and initialisation will be derived from the present operational numerical weather prediction model HiRLAM (see www.hirlam.org). Since the Cabauw site is monitoring the atmospheric column on a continuous basis it will be used to do a critical evaluation of its performance.

In practice, COBEL-ISBA will become a member of the Cabauw Parameterisation Testbed (CPT, see www.knmi.nl/~neggers/CPT). The CPT consists of a number of one-column model versions of climate and weather prediction models that run automatically on a daily basis and are routinely evaluated with daily available observational data. A similar analysis will be done at Schiphol and Wageningen, albeit with a more limited data set of observations that is available at the airport.

Finally, in this project an optimal location at Schiphol will be selected where the observational site at Schiphol needed for the validation of COBEL-ISBA should be located. This obviously has to be a location that is vulnerable to fog. It also needs to be representative for a relevant area of Schiphol airport. Another point of research will be that a climatology map needs to be made that provides information on how often fog has formed *locally* due to radiation or has been formed *elsewhere* and has been transported by advection. Obviously the planned measurement location and the associated single-column model COBEL should be located at a place where *radiation fog* prevails over *advection fog*. For this purpose, results of climatological studies, which will be performed by the Hotspot project "Climatology and Climate Scenario's Mainport Schiphol", will be used.

2.3 . Outlook for research with COBEL-ISBA beyond this project.

In this project we concentrate on the implementation and evaluation of COBEL-ISBA on Schiphol airport with a limited set of observations. Beyond this project we foresee several new research topics related to the Schiphol situation:

1. Implementation of a measurement site at Schiphol for a more extensive validation of the COBEL-ISBA model,
2. Improvement of the physical formulation to optimise fog and low clouds representation on the following topics
 - Effect of the cloud droplet number concentration on the gravitational settling,
 - Improved representation of mixing in the stable boundary layer,
 - Improvement of the relationships between liquid water, cloud droplet number concentration and visibility;
3. Use of COBEL-ISBA to derive climatology's of fog and low clouds in a future climate. By subjecting the 1D column model with future climate synoptic large scale conditions as produced by (regional) climate models, assessments can be made on the climatology of fog and low clouds in future weather conditions. By the same token the influence of changing soil and vegetation conditions on the climatology of fog and low clouds can be explored.
4. Explore the use of tower observations, e.g. from the Cabauw site, to initialise the atmospheric profiles in COBEL-ISBA through the 1D-data-assimilation system that is available in this model. This is a crucial step if we want to use COBEL-ISBA as short-term forecast tool. Past experience with this model (Bergot et al. 2006) has shown that the improved forecast skill of this model can only be achieved when the model is accurately initialised.

◆ **Relevant literature:**

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◆ **Expected scientific output:**

- Academic version of the 3D mesoscale model HARMONIE, that can be used by the Dutch research community to study local weather processes related to climate change;
- Improved 3D model tool that can be used to compute critical weather parameters, such as wind, precipitation and visibility, for Schiphol airport in a future climate;
- Improved 1D model tool to compute specific weather parameters

- related to fog and low clouds at Schiphol airport;
- Improved knowledge on the onset, growth and decay of radiation fog;
- Improved knowledge on meteorological processes which are crucial for a safe and efficient exploitation of Schiphol airport in a future climate;
- A single Column Model tool along with an observational data base that can be used by the research community to further study the physics and dynamics of fog. A license agreement is needed for using the model;

4. Societal aspects

◆ Societal relevance and connection to the hotspot and/or KKF research agenda:

Schiphol Mainport and its network of international connections is of vital importance for the competitive position of the Randstad in the Netherlands and therefore for the Dutch economy. Schiphol is a primary hub for Air France – KLM in the region, resulting in a strong economic position for the Netherlands in Europe and in many employment opportunities. The airport and the surrounding area are vulnerable to changes in our climate. Schiphol is situated 4–6 m below sea level in the Haarlemmermeer, one of the most complex and vulnerable urban areas of the world. An accelerated sea level rise together with continuous land subsidence and periods of intense precipitation and drought, forces Schiphol to investigate which adaptations are necessary in the design of Schiphol Mainport and in the use of the whole Schiphol region to make Schiphol “Climate Proof”. Regional issues such as land-use, infrastructure, housing, flight safety, noise, air pollution and water management may be affected by climate change. Locally, climate change affects the weather conditions at the airport which has a direct influence on the airport capacity, in particular on the peak hour capacity, which is of vital importance for the position of Mainport Schiphol and is a limiting factor for a possible future expansion of the airport.

Since the airport has been expanded in 2003 with the Polderbaan, the airport operation has become more sensitive to fog, and the wind climate near the Polderbaan seems to differ from other locations at the airport. Analysing local airport climatology’s and correlations between airport measurements, should reveal whether the critical weather conditions at the airport have changed, and whether operations would profit from weather information from more than one location at the airport. This information will be provided by the Hotspot project “Climatology and Climate Scenario’s Mainport Schiphol”. The correlations will also help us to find appropriate locations at the airport to do additional and new measurements for climate monitoring and model validation. In this respect there is also a link with the Hotspot project “Wind and Visibility Monitoring System (WindVisions)”.

To increase our insight in the future weather conditions at Schiphol airport, HARMONIE and COBEL will be used to downscale large scale future climate conditions, as produced by climate models, to the local scales at the airport. The large scale conditions, such as wind and temperature at upper-air levels and sea-surface temperature at mean sea level, will be provided by climate models from the KKF / Model Platform – Future Weather (RACMO).

◆ Stakeholders involved in the development of the research proposal:

The main stakeholders that have been involved in the development of this research proposal are the Schiphol airport authorities (AAS) and Air Traffic Control in the Netherlands (LVNL). KNMI has a long term relation with these stakeholders as a provider of operational weather information for aeronautical purposes. The stakeholders have a strong interest in learning how climate change affects the critical weather

<p>◆ Contribution to national and/or regional adaptation strategies:</p> <p>◆ Knowledge transfer:</p> <p>◆ Usefulness of research for other regions and settings:</p>	<p>conditions at the airport. Their own adaptation strategies will highly depend on that. In order to find a proper balance between research and development (which is the main objective of this project) and the operational requirements of Schiphol operations, we will collaborate with the Knowledge and Development Centre (KDC) of Schiphol. In the KDC all stakeholders of operations at Schiphol, AAS, LVNL and also KLM airlines, are involved.</p> <p>Others that have been involved in the development of the proposal and are interested in the output of the project are:</p> <ul style="list-style-type: none"> ▪ The international HiRLAM-ALADIN cooperation program, w.r.t. the development of the academic version of HARMONIE; ▪ Meteo France, w.r.t. the development of the one-dimensional column model for fog and low clouds at Schiphol airport. <p>This project will provide several model tools, such as an academic version of the high-resolution model HARMONIE that can be used to study the influence of global climate change and regional adaptations (e.g. in spatial planning and land-use) on the local climate at Schiphol airport and the effect thereof on Schiphol operation. These tools can help Schiphol to determine which adaptation strategies are most effective to sustain a durable operation of the airport in the future.</p> <p>Knowledge from this project will be transferred by:</p> <ul style="list-style-type: none"> ▪ Providing a model infrastructure to universities and (inter)national research centres; ▪ Providing local observational data for model validation, e.g. from the Cabauw measurement site and from Schiphol airport; ▪ Providing assistance in transferring data and knowledge from the high-resolution model case studies; ▪ Collaboration with the KDC on the operational requirements for wind and poor visibility safety thresholds at Schiphol airport; ▪ Collaboration with the other projects in KvK / Hotspot Schiphol on airport climatology's and high precision measurements; ▪ Collaboration with the KKF project on "<i>Future Weather</i>"; ▪ Organising project workshops, for example on "<i>The impact of critical weather conditions on Schiphol operations</i>"; ▪ Collaboration with other Dutch (military and civil) airports; ▪ Collaboration with the international HiRLAM-ALADIN program; ▪ Collaboration with Meteo France on research and on their experience with similar problems at French airports; ▪ Knowledge transfer at the HiRLAM/ALADIN conference in 2009; ▪ Publication of the project results; <p>This project provides a modelling infrastructure that can be used by the KKF for development of a non-hydrostatic regional climate model. The modelling tools that will be provided are generic and can be used by various other Hotspots to project large scale climate conditions, for example on wind, temperature and precipitation, to local scales. This is particularly interesting for Hotspots such as Rotterdam region, who is interested to obtain more local information on the effects of climate change on their airport, their harbour and their city climate (heat stress) and on e.g. regional Dutch water boards. Furthermore, knowledge from this project can be used for other (regional) airports in the Netherlands.</p>
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5. Connection with other scientific programs	
<p>◆ Connection with KvR, Habiforum and/or Leven met Water research projects:</p>	<p>This project has been screened for a possible connection with current research projects in KvR and 'Leven met Water'. No connection has been found between our project and 'Leven met Water'. W.r.t. KvR, there is a connection between the regional climate model in KvR and the HARMONIE model. One of the research team members of KvR is involved in our project to strengthen the collaboration.</p>

<p>◆ Conection with other national and/or European research programs:</p>	<p>HiRLAM-ALADIN cooperation program; COST action 722 on short range forecasting methods of fog, visibility and low clouds; GCSS through the Cabauw Parameterization Testbed; GABLS atmospheric boundary layer study.</p>
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6. Milestones

<p>◆ Time plan:</p>	<p>Q1–Q2: Inventory of critical weather parameters at Schiphol; Q2: Development of the interface HARMONIE / RACMO; Q1–Q4: Set up of an academic version of HARMONIE; Q1–Q2: Implementation of the 1D column model COBEL; Q3: Coupling of HARMONIE and COBEL to KPT; Q4–Q5: Validation of basic weather parameters; Q6–Q8: Validation on future and present weather case studies;</p>
<p>◆ Scientific milestones:</p>	<p>Sc1. Q2: Report “The impact of critical weather conditions on Schiphol operations”; Sc2. Q2: Interface between HARMONIE and RACMO available; Sc3. Q2: 1D column model COBEL available; Sc4. Q4: Academic version of 3D model HARMONIE available; Sc5. Q5: Report “Validation of HARMONIE and COBEL on basic weather parameters for Schiphol”; Sc6. Q8: Report “Validation HARMONIE and COBEL on future and present weather case studies for Schiphol”;</p>
<p>◆ Societal milestones:</p>	<p>So1. Stakeholders are involved by quarterly meetings and quarterly progress reports; So2. In (Q1–Q2) stakeholders provide input for the scientific report Sc1. that will be delivered in Q2; So3. In May 2009 the HiRLAM/ALADIN conference will be hold in the Netherlands; So4. In Q3 the results of the scientific report Sc1. will be presented and discussed in the workshop “<i>The impact of critical weather conditions on Schiphol operations</i>”; So5. In Q5 preliminary validation results of HARMONIE for Schiphol airport will be presented to the stakeholders; So6. In Q8 the potential to apply HARMONIE and COBEL to determine changes in critical weather conditions at Schiphol airport, as caused by climate change, will be demonstrated to the stakeholders;</p>

7. Consortium

<p>◆ Project consortium and motivation:</p>	<p>KNMI – government: Provider of weather information for aviation AAS – business: Airport authorities, airport operator, direct user LVNL – government: Air traffic control, direct user WUR – research: University of Wageningen – atmospheric research TU Delft – research: University of Technology – atmospheric research KNMI has a long term relation with AAS and LVNL as a provider of operational weather information for aeronautical purposes. Due to the establishment of the Knowledge and Development Centre, Mainport Schiphol (KDC), in which AAS, LVNL and KLM as airport stakeholders are involved, this relation has been strengthened and extended towards research and development. The universities of Wageningen and Delft have been involved due to their expertise on local weather processes and their interest to use new model components such as HARMONIE and COBEL for general research and for specific research focussing on Schiphol airport.</p>
<p>◆ Research team and competence of the involved researchers:</p>	<p>In the project 5 researchers are involved. The research tasks are divided between KNMI, WUR and TU Delft:</p> <ul style="list-style-type: none"> ▪ KNMI is responsible for project management. In the project KNMI

