Title: Wind, Ice and Snow Load Impacts on Infrastructure and the Natural Environment (WISLINE)

Coordinator: Harold Mc Innes, Norwegian Meteorological Institute
Partners: Norwegian Meteorological Institute (MET), Dept. of Geosciences, University of Oslo (UiO), National Center for Atmospheric Research (NCAR), Kjeller Vindteknikk AS (KVT), Norwegian Forest and Landscape Institute (NFLI).
Associate partners: Swedish University of Agricultural Sciences (SLU)

1. Relevance relative to the call for proposals

Strong winds, atmospheric icing and heavy snowfall are weather phenomena that can cause severe damage to technical infrastructure such as the electric power grid as well as natural environments such as forests. The objective of WISLINE is to improve predictions and design values of atmospheric icing, heavy snowfall and damaging winds in the current climate, and to provide quantitative estimates of changes in these parameters in the future, for evaluating the changing risks of forest wind throw and disruption of technical infrastructures, in particular the electric power grid. In order to meet this objective, the project will: 1) Improve the description of physical processes in the atmospheric models, enabling a better quantification of icing and heavy snowfall events; 2) Establish improved post-processing and bias-correction methods for better assessment of icing and damaging winds. That will serve as input to impact models for analysis of icing on electricity transmission lines and wind-throw and breakage in forest stands in a future climate. 3) Apply the improved physical parameterizations, post-processing tools and bias correction methods, carry out high-resolution simulations of icing conditions and damaging winds in future climates; 4) Develop post-processing tools that can enable users to make better decisions with respect to future weather challenges. All datasets and results of WISLINE will be open to end-users (scientists, forestry management, infrastructure owners, planners, and the public). Open access to data will be made available through data distribution systems operated by MET to support services like the Norwegian National Climate Service Centre portal which is under development to help actors in the public and private sectors alike to take decisions about how to adapt to climate change. MET Norway will through its core mandate, extend the results demonstrated in the project into its base datasets for current and future climate in Norway. This will be to the long term benefit of all climate sensitive societal sectors in Norway.

2. Aspects relating to the research project

Background and status of knowledge: Atmospheric icing is a major weather hazard in many mid- to high-latitude locations in the winter, including Norway. There are mainly three types of atmospheric icing; (1) ‘freezing fog’, i.e., in-cloud icing due to (supercooled) liquid cloud droplets at sub-freezing temperatures; (2) ‘freezing rain’, i.e., icing due to precipitation in the form of supercooled rain drops at sub-freezing temperatures; (3) ‘wet-snow icing’, which is caused by heavy precipitation in the form of wet snow or sleet at temperatures just above freezing. All three types are common in central and northern Europe and North America, with (1) and especially (2) mainly occurring in continental air masses in inland regions, while (3) is most common in coastal regions, such as Iceland, the U.K., Japan and parts of Germany (Nygaard et al., 2013). Icing has been known to cause significant problems for many sectors of society, in particular for power transmission lines, wind turbines, aviation, telecommunication towers and road traffic. An extreme example of (2) is the ice storm that hit eastern North America in January 1998 with more than 100 mm of freezing rain observed in some areas (Gyakum and Roebber, 2001). This resulted in more than 4 million people in the Canada and the United States losing power for days to weeks, or even months and a total economic damage estimated at 4.4 billion U.S. dollars. A recent major icing event in Europe was the wet-snow event in Münsterland in Germany in November 2005, in which 82

transmission towers collapsed, leaving 250 000 people without electricity for several days (Frick and Wernli, 2012).
During the winter of 2013/2014 two 420 kV transmission lines in Southern Norway suffered severe damage due to ice loads exceeding their design values, i.e. observations indicated ice loads four to five times the design value at one location.
Values for extreme wind- , ice- and snow loads with corresponding return periods are used to design technical infrastructure such as bridges, telecommunication towers, and electricity transmission lines. Historically, the design estimation approach in Norway has been based on simple empirical relations developed from a limited number of in-situ observations, and therefore involves considerations that are subjective and based on individual experience. Recent damages on the electric grid show that the traditional approach has problems in predicting representative values in areas with rough and complex topography combined with the advection of warm and moist air masses in the winter season. There is therefore an urgent need to develop a methodology for estimation of such design values in a more objective and consistent way. Preliminary studies within the frame of COST action 727 “Atmospheric Icing of Structures” showed that reasonable ice loads could be obtained by using the microphysical fields from an early version of the Weather Research and Forecasting (WRF) model (e.g. Harstveit et al. 2009; Nygaard 2009). Ice loads calculated from an updated WRF based model archive developed at KVT have made it possible to reproduce and estimate the return periods of the 2013/2014 winter’s icing events. There is however a large potential to further develop these objective methods, and use the tools within a consistent NWP model framework for quantification of changes in the icing climate in Norway.
In forests wind and heavy loads of snow, rime and ice can cause wind-throw or stem breakage. Wind-throw has been the most damaging agent in Europe’s forests during the last 150 years, and it has increased considerably during the last 50 years in Europe (Schelhaas et al. 2003), mainly driven by changes in forest management (Nilsson et al. 2004, Bengtsson and Nilsson 2007). The risk for such damage is expected to increase further with climate change due to a slight increase in windiness, reduced root anchorage due to more rain and wetter soils during the storm season (Kamimura et al. 2012), a reduction in the depth and extent of frozen soil (Kellomaki et al. 2010) and increased frequency of heavy snow fall (Gregow et al. 2011). The Gudrun storm may serve as an illustration of possible future damage events. When it hit Sweden on 8th January 2005, it followed a period of 2 weeks with heavy rain. Increased attacks by the spruce bark beetle *Ips typographus* can be expected after wind and snow damage, in particular with increasing temperatures (Schlyter et al. 2006). Falling trees or tree tops generate considerable damage on infrastructure, mainly roads, railways and power lines. The damage risk can be decreased through appropriate forest management, and scenarios make up an important basis for decisions on altered management. This includes changing tree species, providing the trees generous space at low age (increasing ‘single tree stability’), avoidance of late and heavy thinning (increasing ‘social stability’), and careful placement of stand edges after clear-cut in the landscape (Nielsen 2001, Albrecht et al. 2012).
Approaches, hypotheses and choice of method: In order to investigate future ice, snow and wind loads, an extensive knowledge about such loads in the present climate is required. We will provide this by improving the description of the cloud microphysical processes that occur in particular in cold clouds. Our choice of model is the operational limited area atmospheric forecast model system used at MET Norway, the non-hydrostatic AROME model at 2,5 km resolution, which is run in forecast mode four times per day using ECMWF forecasts as initial and boundary conditions. This model system is the basis for the NWP services at MET Norway, including the products on www.yr.no, and it is continuously improved in a European collaborative project involving 11 European meteorological services, including the Nordic ones. The choice of this model as a basis for the research proposed in WISLINE ensures that

the products will be widely used, at the same time as there is very extensive, rolling validation and verification of the quality model and its products against observations. In the project the model with the improvement in cold cloud description that is the goal of WISLINE, will be used to demonstrate the development of long hindcast datasets. Advanced algorithms for the post-processing of results from the AROME 2,5 km model will be developed to assess local wind and icing conditions. The first step of the project will be to improve the treatment of cloud microphysical processes in AROME, thereby enabling significantly improved predictions of icing events (WP1). This will be carried out mainly as a Ph.D. project at the University of Oslo, in collaboration with internationally leading experts on icing modeling at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, USA and researchers at the Norwegian Meteorological Institute (MET) and Kjeller Vindteknikk AS (KVT).

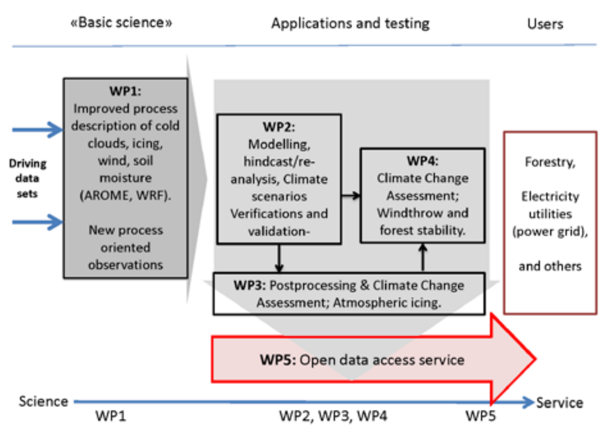

Figure 1: The project structure

The second step will be to establish a high resolution hindcast for the present climate, which allows verification of icing simulations against observations (WP2). When the verifications indicate that the methods are capable of producing a high resolution dataset of high quality for the present climate, the third and final step will be to use the same methods to downscale data from one or more regional climate models (RCM), providing a demonstration of a high resolution dataset for the future climate. Post-processing algorithms for impact studies will be developed and applied to the down-scaled datasets. The impacts will be demonstrated through application studies for the power grid (WP3) and forests (WP4). The open access to data and results from the project will be implemented and managed in WP5.

3. The project plan, project management, organisation and cooperation

WP1. Improved predictions of atmospheric icing by upgrading the cloud microphysics scheme in MET Norway's operational AROME weather prediction system
Lead: Jón Egill Kristjánsson, Co-lead: Roy Rasmussen (NCAR).
Personnel funded: Ph.D. student (MET/UiO), Greg Thompson (NCAR), Bjørn Egil K. Nygaard (KVT), NN (MET)

The current AROME cloud microphysics scheme is based upon Cohard and Pinty (2000), which when followed backward through the literature, has physical processes similar to Ferrier (1994), Rutledge and Hobbs (1984), and Lin et al (1983). Many of the WRF model microphysics has similar lineage and similar outcomes, one of which is the tendency to predict too much ice phase rather than liquid. The recent study by Liu et al. (2011) showed how the schemes with roots in Lin et al. (1983) all predicted too much ice and too little liquid and resulted in too much surface precipitation compared to observations. In contrast, the Thompson et al (2008) and Morrison et al. (2009) schemes predicted much more liquid and less ice with surface precipitation that very closely matched the observations. There were eight processes thought to be responsible for the behavior of Lin et al. (1983) based schemes:
(i) ice initiation and vapor depositional growth, (ii) snow riming to form graupel, (iii) freezing of rain to form graupel, (iv) collisions of graupel and snow, (v) collisions of rain and snow, (vi) collisions of rain and graupel, (vii) snowfall speed and (vii) cloud to rain conversion.

Each of these processes can be separately isolated and developed further in the AROME microphysics package to reflect the experience reported in Thompson et al. (2008) as well as more recent findings. Initial experiments will be carried out in idealized or real simulations. Then simulations will be carried out over southern Norway, using icing measurements from Statnett's test span at Ålvikfjellet in Hardanger for validation. Together with cameras this enables quite accurate monitoring of the cylindrical growth of ice on the wire. Assuming a reasonable range for cloud droplet number concentrations, combined with measured wind speed allows us to deduce a reasonable estimate of the supercooled liquid water content. This is a location with strong forcing by vertical motions, and is as such a critical validation point. In addition, precipitation gauge measurements will be used for validation, because the amount and type of precipitation is a good indicator of how well the cloud microphysics scheme is able to handle supercooled water and wet snow (Liu et al., 2011), which are the causes of icing that we focus on in WISLINE. For the validation we will also install a Rosemount icing detector for detection of supercooled liquid water content at an icing exposed location in Norway. In addition to the conventional network operated by MET, the WMO SPICE site at Haukeliseter will be particularly valuable in this regard. Aggregating the findings from the process description improvements, a new AROME microphysics scheme is achieved which is expected to produce more liquid water content, less ice, and less surface precipitation. Furthermore, these changes are expected to improve the quality of the prediction of icing of ground objects. This stepwise approach would be highly instructive and well suited for a Ph.D. project, the focus being on physical processes and their formulation, rather than on parameterization schemes, which sometimes tend to be regarded as 'black boxes'.

Suggested approach:

1) Make initial changes to the existing AROME microphysics scheme to make it more similar to Thompson et al (2008) microphysics scheme.
2) Implement Thompson scheme into AROME
3) Compare performance of (i) current AROME and (ii) AROME with Thompson scheme, using data from Norwegian sites and previously validated WRF/Thompson simulations for validation
4) Based on 2), improve specific formulations in AROME; re-run and validate.

Deliverables:

- An improved AROME cloud microphysics scheme, validated against the Thompson scheme and observations (month 24)

Societal impact: Significantly improved forecasting of icing events and icing occurrence, with benefits for: (i) Power Transmission Line design; (ii) Wind Turbine operations; (iii) Location of telecommunication towers; (iv) Aviation planning and de-icing; (v) Road traffic warnings and closures

WP2. Establish high-resolution dataset for past, present and future weather and climate.
Lead: Jan Erik Haugen (MET)
Personell funded: Hilde Haakensen, Trygve Aspelien/Dagrun Vikhamar Schuler, Cristian Lussana (all MET).

Impact modelling often requires other climate data for the past and the future with different spatial and temporal characteristics than directly provided by the climate models. In WISLINE we will take advantage of the improved physics and the high spatial and temporal resolution in the AROME 2.5km model and improved global reanalysis data (ECMWF ERA-interim or the replacement ERA-SAT, expected available from 2015) to establish a consistent hindcast dataset for Norway. Depending on the quality of the results of the model improvements, a hindcast calculation will be carried out covering one decade or more to investigate its statistical properties against observations. The next step is then to carry out a 50 yr hindcast as a part of the core mission of MET Norway. This will probably be done outside of this project. The operational use of a similar system for numerical weather prediction at MET is a strong support for long term building of competence in the analysis of uncertainties and limitations in such data. A similar approach will be taken to provide climate scenarios by downscaling of output from RCM at 12 km from the EURO-CORDEX simulations (Jacob et al, 2014). Further downscaling of surface characteristics will be obtained by new and improved methods for post-processing (WP3) and adjustment of data to high-resolution terrain and different surface types in Norway. High resolution model data at 1 km scale for wind, humidity and other parameters relevant for the impact studies in WP3 and WP4 will be obtained by applying surface models (e.g. Surfex package for assimilation and prediction of near surface parameters in offline modus), and forcing data from a 2.5km model simulation (AROME). The adaptation to high resolution scale will include more detailed schemes for simulation of the snow-package with improved process description of extreme climate conditions, caused by natural variability and long term climate trends. MET also holds a 1x1 km gridded time series dataset of observational records for surface temperature and precipitation. An update of this data set is expected in the near future and will be included in the surface assimilation method for adaptation of near surface parameters from 2.5km data to a 1km. The 1km data combined with post-processing techniques will provide necessary climate parameters as input to further impact modelling. The use of similar techniques for past and future climate will provide updated knowledge of the spread in the computations for future climate at relevant scale based on the latest data available from global and regional models.

Deliverables:

- Demonstration of high-resolution hindcast at 2.5km forced by global reanalysis data (ERA-Interim/ERA-SAT).
- Comparative hindcast at 2.5km with new microphysics scheme (Thompson).
- High-resolution surface modelling at 1km forced by data from hindcast 2.5km with use of gridded observations.
- Demonstration of scenario calculation at 2.5km and high-resolution surface modelling at 1km with bias-correction against data created in the hindcast period.
- Validation of procedure across time scales from historical climate to future scenarios.
- Establish data archive and interface with impact modelling in WP3 and WP4.

Societal impact: A new high-resolution climate dataset and consistent prediction across different time-scales that will benefit users of weather data for impact analysis, operations and climatological design values.

WP3 Climate change influence on the geographical distribution of wind and icing design loads in Norway

Lead: Bjørn Egil K. Nygaard, KVT Personnel funded: PhD-student (MET/UiO),NN(UiO), Greg Thompson (NCAR), Harold Mc Innes(MET), Thomas Nipen (MET), Cristian Lussana(MET), Øyvind Byrkjedal (KVT), Knut Harstveit (KVT), Johannes Lundvall (KVT)

WP 3.1 Atmospheric icing.

In addition to standard weather elements like wind temperature and precipitation, atmospheric icing depends on meteorological fields which are not routinely measured at regular weather stations. In-cloud icing depends on the cloud liquid water content and droplet size distribution while wet snow icing is dependent on the structure and liquid fraction of wet snowflakes. To describe the icing climatology, both present and future, we depend on the atmospheric models' ability to realistically simulate these meteorological parameters (WP1).

In order to study changes in the icing climatology we will run the AROME NWP system with an improved and validated cloud microphysics scheme (from WP1) for present and future

downscaled conditions. To make the study relevant for structural design, the model data must be further processed through a time dependent ice accretion model, to estimate maximum accumulated ice loads, e.g. extreme ice loads with return a period of 50 years.
Currently, design loads for new transmission lines, television towers and wind turbines in Norway are based on a WRF (Thompson microphysics) 1979-2014 reference data set produced by KVT. Different icing post processing modules (time dependent ice accretion models) have been implemented and optimized based on data from various projects over several years (e.g. Byrkjedal & Berge 2009, Nygaard et al. 2011, Nygaard et al 2013). In WISLINE these modules will be further developed and coupled with the AROME NWP system developed in WP1. New icing measurements from the test span at Ålvikfjellet in Hardanger as well as known historical events will be used for validation.

Suggested approach:

1) Implement current post processing routines for ice load calculations using AROME data.
2) Validation with available observations (e.g. Ålvikfjellet in Hardanger) and historically used design values. Perform case studies to demonstrate to which extent the upgraded microphysics of AROME improves the icing simulations (Proof of concept for WP2).
3) Develop recommendations on the use of AROME data in combination with other downscaling model tools for design ice load calculations. Apply the improved AROME and run it for the years 2060-2070 based on output from CMIP5 21st century runs with NorESM, the Norwegian earth system model, to obtain a future icing climatology for Norway, utilizing the post processing methods developed in WP 3.1. Simulations of present and future climate will be carried out in collaboration with WP2.

Deliverables:

- Proof of concept: Applying AROME with Thompson scheme for ice load calculations using the ice accretion models currently used with WRF at KVT. Validated with measurements from Ålvikfjellet and possibly other test sites.
- Report on recommendations on the use of AROME data in combination with other downscaling model tools for design ice load calculations.
- Simulated future changes in icing climatology over Norway using the new improved AROME scheme.
- Provide ice and snow load estimates to WP4.

WP 3.2 Extreme wind in complex terrain.

The aim is to develop objective methods to calculate extreme winds based on model generated wind climatology, e.g. based on the atmospheric hindcast for Norway applying AROME 2.5 km (WP1, WP2). The modeled energy spectra of NWP models typically show a deficit in the high frequency part which implies an underestimation of extreme winds (e.g. Larsén et al 2012). This limits the possibility to use the modeled output directly for estimation of extreme winds. The large sub-grid scale variation in extreme winds in complex terrain is another limiting factor.
Guidelines for doing site specific evaluation of extreme wind conditions are given in the Norwegian Standard (EN 1991-1-4:2005+NA. 2009). Today’s standard applies to reference extreme wind data on county scale.To take into account local conditions on the sub-grid scale several post processing tools will be considered and improved. The algorithms for downscaling of the results either statistically or dynamically will be further developed to adapt the model results to local sub-grid conditions with the aim to supply average 10 minute wind speed and 3 second gust values at a return period of 50 years. Linearized flow models e.g. Wasp Engineering (Mann et al, 2004, Jackson and Hunt, 1975) which is widely used for wind power applications to extrapolate wind fields from a mast position or modeled grid

position to local scale have been shown to produce unphysical extreme values in complex terrain. In areas with complex terrain we will investigate the use of high resolution NWP simulations. Experience with such setups using WRF with 500 m grid spacing has shown that the model's ability to describe extreme winds caused by mountain waves depends strongly on the grid refinement.

Suggested approach:

1) Carry out calculations of extreme wind from the hindcast runs and compare the result with data from selected observational sites
2) Study different techniques for downscaling of extreme winds from the NWP calculations and their applicability in complex terrain
3) Develop recommendations and methods to combine different downscaling methods suitable for different terrain
4) Apply the recommendations to future climate simulations.

Deliverables:

- Recommendations on the use of AROME data in combination with other downscaling model tools for the calculation of extreme winds in Norway.
- Provide data on high wind speed episodes to WP4

Societal impact: Valuable information for adaptation to climate change in Norway in the 21st century, in particular to societal sectors vulnerable to icing events, such as power transmission companies, wind power companies, aviation authorities, road maintenance authorities.

WP4. Forest damage from wind and snow (NFLI, SLU, MET)
Lead: Svein Solberg (NFLI), Personell funded: Nikolas von Lüpke (NFLI), Kristina Blennow (SLU), Ole Einar Tveito (MET)

Damage to forest by wind and snow occurs if the load from wind and/or snow exceeds the resistance of the forest to this load. Factors such as tree species, tree height, time since last thinning, and rooting conditions have been shown to correlate with observed damage (Quine and White 1993, Mayer et al. 2005, Schmidt et al. 2010, Albrecht et al. 2013, Bonnesoeur et al. 2013). Recently, a near-linear relationship between thinning intensity and damage caused by storm and snow was found (Wallentin and Nilsson 2014). However, the load from wind and snow varies in the terrain at different scales. For example, the exposure to strong wind, and hence the wind load depends on the topography; a forest on the top of a hill is often exposed to stronger wind than a forest in a valley and the clear-felling of adjacent forest will expose the forest to higher wind loads. There are two main model categories for snow and wind damage risk, i.e. mechanistic (Peltola et al. 2000 Blennow and Sallnas 2004, Seidl et al. 2014) and statistical models (Jalkanen and Mattila 2000, Solberg et al. 2008, Schmidt et al. 2010, Solberg et al. 2014).

Suggested approach: In the present project, we will fit a statistical model, either using logistic regression or Generalized Additive Model (GAM) (Schmidt et al. 2010) to historical wind and snow damage data from the National Forest Inventory (NFI) with some 12 000 sites (plots) around Norway from 1996 and later. Data on wind and snow, as well as soil wetness will be input from WPs 1-3. An index reflecting the influence of the topography on the wind speed will be generated from the Norway-wide DTED10 digital elevation model. Soil data from field inventory on the NFI plots, supplemented by data from the Norwegian geological survey (NGU), will be used. The model will be validated with damage data from the forest officers' plots data with 700 plots containing 40 000 trees having annual observations during 1988-2007, as well as from recorded damage in the forest damage database at NFLI and Skogbrand insurance company archives. Given the risk model we will predict current and future wind and snow damage for the 3 km x 3 km grid of the NFI.

Deliverables:

1) Model: Statistical model on risk of snow and wind damage including estimated accuracy.

2) Norway wide maps generated from the 3 km x 3 km grid used by the NFI plots. This includes (i) risk given current climate and current forest condition; (ii) risk given the climate scenario and current forest condition; (iii) increase in wind damage risk; and (iv) increase in snow damage risk.
3) National and regional summary statistics (m^3 damaged stem wood) for various alternatives, i.e. (i) current climate with current forest condition, (ii) scenario climate with current forest condition; (iii) and (iv) will be repetitions of (i) and (ii) with altered forest management for increased stability, i.e. increased d/h ratio, tree species changes on high risk sites, and avoidance of late and heavy thinning; (v) scenario climate and a continued accumulation of old trees due to low harvesting.
4) A case study on a simulated, extreme storm event over the Oslofjord area, including estimated damage volume, a damage map and a timeline of events, to be provided to forestry and other users as input to an ongoing planning of readiness.
5) Manuscript on the model submitted to a peer-reviewed international journal.

Societal impact: The results of this WP will increase the understanding of future forest damage, increase awareness, and make up a basis for readiness within forestry as well as within infrastructure and other sectors affected by it. In addition, Norwegian forestry may upon the deliveries from this WP consider alterations in forest management in certain regions and certain sites to reduce future risks.

WP5 Data Services. Lead: Harold McInnes (MET) Personell: N.N (MET)

A sustainable operation of the atmospheric model framework and access to the resulting datasets is a main deliverable of the project. MET Norway will provide continuous access to the derived datasets through its operational data portals for online data sets. Such data portals rely on metadata which refers to online datasets, and MET is using THREDDS Data Server to facilitate the access layer to data, effectively offering various access protocols. This data infrastructure supports the requirements of e.g. Copernicus Climate Change Services, and will allow users to view, access, download and utilize the data for their own applications. During the project period WP5 will prepare, manage and publish the relevant data sets. The output data-sets from WISLINE are potentially useful for key users of the Norwegian Centre for Climate Services, and will thus be made available for dissemination through the NCCS web portal. MET Norway will also use the results from the project in advising core societal sectors on meteorology and climate, as a part of its governmental core mandate.

Deliverable: Open data access through a MET operational data portal.

Project management, organisation and cooperation: WISLINE brings together researchers from Norway, Sweden and the USA representing theoretical and applied meteorology, climatology and forestry. The project will be coordinated by the Norwegian Meteorological Institute. Project coordinator will be Dr. Harold Mc Innes, who has a broad experience in theoretical and applied meteorology and climatology. He will be supported by Professor Jón Egill Kristjánsson (UiO), Dr. Jan Erik Haugen (MET), Dr. Bjørn Egil K. Nygaard (KVT) and Prof. Svein Solberg (NFLI) as WP leaders.

The project team includes Dr. Greg Thompson and Prof. Roy Rasmussen, internationally leading experts on icing modeling at the National Center for Atmospheric Research in Boulder, Colorado, USA and Prof. Kristina Blennow, a recognized expert on assessment of wind damages on forests at the Swedish University of Agricultural Sciences.

The project is organized in five work packages (WPs), representing scientific development, implementation and validation, post-processing, user-tailoring, climate change impact demonstration studies, and dissemination.

Budget: The budget is provided in the application form. The improved microphysics in the atmospheric models provided by WISLINE will also be implemented in MET's operational weather forecasting models. Since these developments will benefit MET's continuous efforts to improve the NWP models MET will contribute with a considerable in-kind contribution to the project. The University of Oslo also provides a considerable in-kind contribution through supervision of the Ph.D. student by Prof. Jón Egill Kristjánsson, who is an expert on parameterization of cloud processes.

4. Key perspectives and compliance with strategic documents

Compliance with strategic documents: The proposal fulfils the long-term strategic objective of the applicant institution MET to improve the understanding and ability to predict hazardous and extreme weather conditions, and to make the society better prepared to reduce the consequences of such events. The results and data will be freely accessible by the public through the operational data access services at MET. The project will improve gender balance through a female PhD candidate. One of the work package leaders (Dr. Nygaard, age 33) is a young scientist.

Relevance and benefit to society: WISLINE will give better understanding and information on atmospheric icing and extreme wind and their impact on the electricity grid and forests. It will provide information that can enable society to reduce its vulnerability to damages caused by wind and icing by including this information into design value calculations and forestry management practices. See also relevance and benefit in the WP descriptions above.

Environmental impact: We cannot see any negative effects related to the proposal. The project will provide results that can be used to reduce and prevent damages related to technical infrastructure and the natural environment. Hence it will have a moderately positive effect for the environment.

Ethical perspectives: There are no ethical issues identified within the project.

Gender issues (Recruitment of women, gender balance and gender perspectives): The portion of female researchers in this field of research is relatively low. In this application, the project team has been selected based on their areas of expertise. However, the PhD candidate Bjørg Jenny Kokkvold Engdahl (MSc 2011, University of Oslo) is female. Female researchers will be involved in WP2 (Hilde Haakenstad, Dr. Dagrun Vikhamar-Schuler both at MET) and WP4 (Prof. Kristina Blennow, SLU).

5. Dissemination and communication of results

<u>Dissemination plan:</u> A dissemination plan is provided in the application form. Access to results is also described in the deliverables of WP5.

<u>Communication with users:</u> We will invite users within electricity transmission systems, forestry and others to a user contact group in order to have regular communication on results and needs.

6. Additional information specifically requested in the call for proposals

Only information that is explicitly requested in the call for proposals and is not included in the points above should be provided here.

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