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POTENTIALS AND CHALLENGES OF SNOW DRIFT SIMULATION FOR AVALANCHE WARNING

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INTRODUCTION

Avalanches are mostly triggered by a critical snow depth. The highest snow depths are generally accumulated in leeward slopes, chutes, and dingles, by wind and snow drift. In this work a critical review of potentials and challenges for snow drift simulation models is given. An enhanced snow drift model will be presented using a multiphase algebraic slip approach, time dependent boundary conditions (BCs) from Numerical Weather Prediction (NWP), turbulent air flow and a turbulent drift model. The model is validated by measurements from weather stations at the Planneralm (Austria, Styria). Parameter studies evaluate the influence of snow properties in comparison to wind speed.

REVIEW OF SNOW DRIFT MODELS

The foundation for our current understanding of aeolian snow and sand transport was introduced in the 1940's. In the 90's, a more formalized classification of wind induced particle transport and a deeper understanding of the saltation transport mode was achieved. End of the 90's, first transient 3-D snow drift models were introduced, where the wind was determined by computational fluid dynamics. The saltation transport mode was computed separately by typical grain trajectories, which included ejection of grains due to impacts of other snow particles. In 2000's substantial suggestions and improvements concerned the combination to snow cover models, a simplified deformation of the wind field within the saltation layer and discussions of the snow drift suspension as a continuum. Currently, there are several three-dimensional simulation models available, including variable topography, different snow climates and spatially distributed meteorological models.
However, several main areas are identified which appear most critical for achieving improved results in snow drift simulations.

1. Application of high-resolution local wind fields, including transient behaviour.
2. Ground surface modelling and the change of surface shape during erosion / deposition events.
3. Assessment of turbulence effects in the air flow.
4. Erosion and deposition behaviour of snow with respect to numerous physical properties like temperature, grain size, wind speed, gross density and erosion rate.

ADVANCED SIMULATION BY ALGEBRAIC SLIP MODEL & TIME DEPENDENT BC'S

A fully turbulent non stationary simulation approach is presented. The main differences to other models are a multiphase Algebraic Slip Model for drifting and blowing snow and time dependent boundary conditions for driving the wind field. These are obtained by a mass conserving optimisation approach applied to meteorological data. The snow particles in saltation and suspension are accounted as a continuous phase. Therefore no separate numerical domains are required. Snow transport and the computation of shear stresses for snow erosion and deposition is affected by the turbulence. The topology is modelled dynamically to account for the surface change by deposition and erosion.
The model and it's results are demonstrated for Planneralm in Austria. The wind flow is computed by extracting the time dependent BCs from the NWP model ALADIN-Austria. The Navier-Stokes Equations are solved by a commercial CFD solver . The unsteady wind field is computed based on an

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hourly weather forecast. The model results are compared to meteorological measurements at reference stations. The computed snow depositions are validated by continuous automatic snow height measurements and snow poles for major drift occurences in winter 2009/10 and 2010/11.

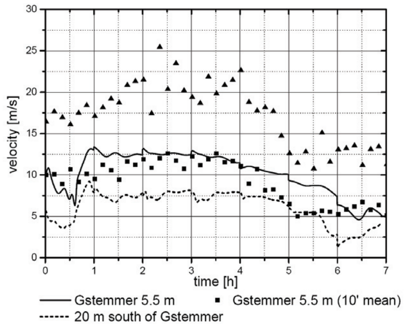

Fig. 1 Comparison of the measured (symbols) and computed (lines) wind speed at the Gstemmer peak.

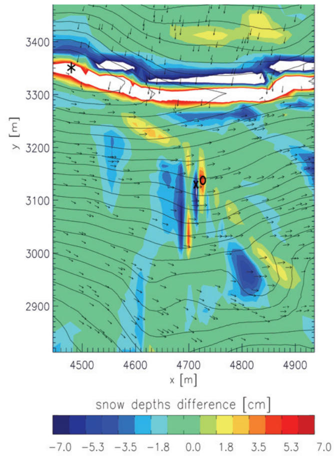

Fig. 2 Computed drift distribution

INFLUENCE OF DIFFERENT SNOW PROPERTIES TO SNOW DRIFT

The dependency of the computed snow depth's to various snow property parameters is analyzed. Some important results areThe dependency of the computed amount of redistributed snow on various snow properties is analyzed. Some important results are:

1. Particle density: Varying the density between 200 and 900 kg/m3, the amount of redistributed snow changes less than 50%. This holds for accumulation as well as for erosion zones.
2. Grain diameter: The amount of redistributed snow depends linearly on the grain diameter. At approx. 1.5 to 2mm grains snow drift appraoches a maximum level of erosion and sedimentation.
3. For low cohesion the amount of redistributed snow changes just about 15%, when increasing the cohesive force approx. by a factor 10. Snow drift, however, stops, if the cohesive force per unit area exceeds the air borne shear stress.
4. Amount of erosion with respect to the air borne shear stress: Using a parameter magnitude as suggested in literature leads to no drift at Planneralm. Increasing the parameter by one order of magnitude delivers good correlation of measurement and simulation. Increasing the parameter by factor 100, results in change of snow height by approx. factor 2 to 3.
5. Saltation mass flux: A modification of the friction velocity by the factor two leads to a change of the snow particle flux rate by the factor 9.

CONCLUSIONS

The determination of time dependent boundary conditions from macro- and meso-scale NWP models by optimization techniques for micro-scale alpine wind field computations is a good base for snow drift simulations. The results of the snow drift simulation fit the measured data satisfactorily.

The parameter study shows clearly the influence of important snow property parameters to the simulated snow height. However, the snow drift simulation is much more sensible to the variation of wind conditions than to the variation of snow properties in typical ranges. An accurate assessment of the local wind field and it's turbulence effects is inevitable for predicting snow drift.

Nevertheless it is acknowledged that snow parameters have an important role and additional work has to be done on the huge effect of the metamorphosis of snow. Additional work is also suggested for computing snow drift during precipitation.

Keywords: snow drift, avalanche warning, CFD, optimization, time dependent boundary conditions, algebraic slip model, aerodynamic entrainment