33rd International Conference on Alpine Meteorology
ICAM 2015
Innsbruck Austria
31 Aug - 04 Sep 2015

unibz Fakultät für Naturwissenschaften und Technik
Facoltà di Scienze e Tecnologie
Faculty of Science and Technology

EURAC research

University of Zurich[UZH]

P3.10

EMERGE Project
'Retreating glaciers and EMERGing new ecosystems in the Southern Alps'

# Simulation of snow dynamics at different scales in a high-elevation catchment

Michael Engel[1], **Giacomo Bertoldi**[2], Claudia Notarnicola[3], Stefano Endrizzi[4], Georg Niedrist[2], Francesco Comiti[1]

[1] Faculty of Science and Technology, Free University of Bozen-Bolzano, Bolzano, Italy
[2] Institute for Alpine Environment, EURAC, Bolzano, Italy
[3] Institute for Remote Sensing, EURAC, Bolzano, Italy
[4] University of Zurich, Switzerland

## Introduction

- Fresh water in mountain regions is mainly governed by snow cover distribution, snow amount and timing of melt depending on local climatic conditions.
- Meteorological conditions and topography control the spatial heterogeneity of snow cover in complex terrain and call for the use of **physically-based distributed hydrological modelling** of **snow covered area (SCA)** and of **snow water equivalent (SWE)**.
- However, the complexity of such advanced modelling requires an accurate evaluation of model results against ground observations and satellite products both at the **point** and **catchment scale**.

## Objectives

This work aims to:

(i) assess the model validation of GEOtop 2.0 at the point scale in order to improve performances at the catchment scale

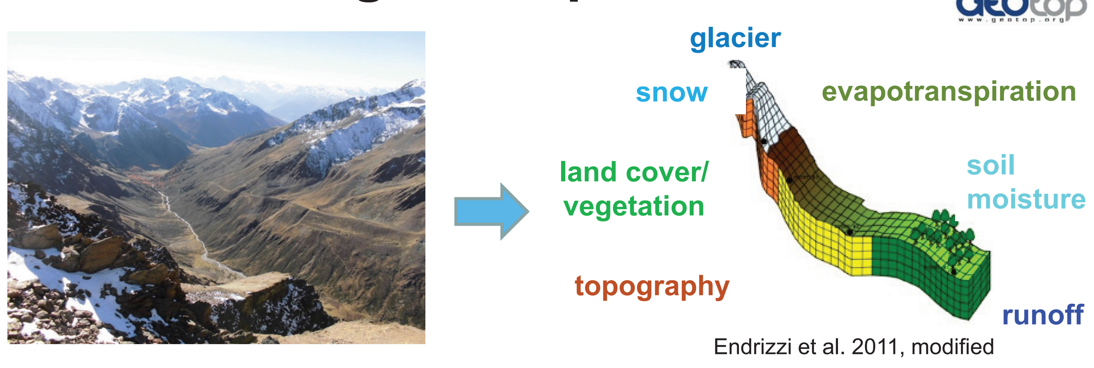
(ii) verify the usefulness of using multiple types of observational data (snow, satellites, tracers, discharge) in order to assess the physical consistency and to reduce the equifinality of the model output.

## Study site

- The study area (61.7 km²) is located in the Matsch valley (South Tyrol, Italian Alps).
- The Saldur river drains the valley with an elevation range between 900 m and 3,700 m a.s.l..
- A small glacier is present at higher elevations (current extent of 2.8 km²).
- Mean annual temperature is 6.6°C and total precipitation is 569mm at 1570 m a.s.l. (about 1000-1500 mm at higher elevations).

The upper Mazia Valley seen from the stream gauge ´LSG´at 2150 m a.s.l..

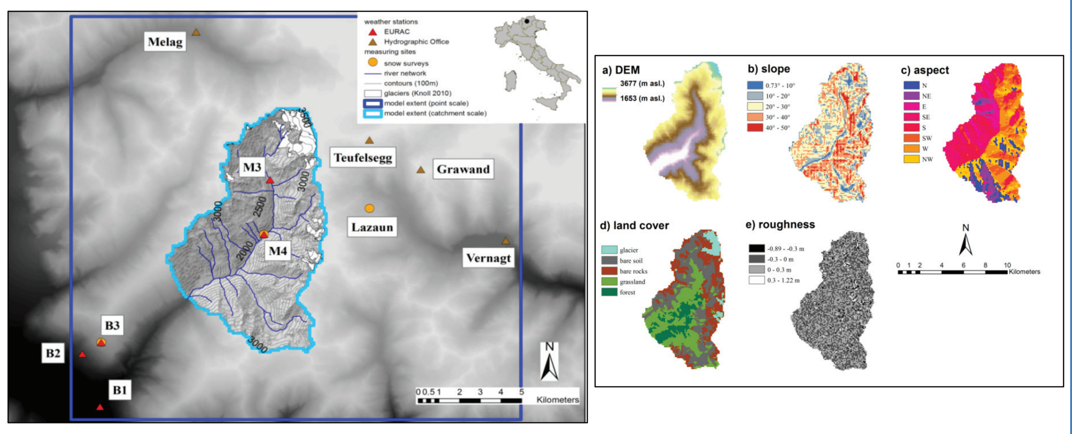
## Physically-based hydrological modelling Geotop 2.0




Endrizzi et al. 2011, modified

- Solves energy budget and water budget for complex topography Rigon et al. 2006, Endrizzi et al. 2014
- Environmental input data spatially interpolated using Micromet Liston and Elder 2006
- Multiple snow layer discretization Endrizzi and Marsh 2010

## Model setup




- 100 m digital elevation model (DEM)
- CORINE90 land cover, modified glacier extent
- Meteorological data from 7 weather stations
- Lapse rate of air temperature (dynamic)
- Calculation time step: 1h, aggregated to 24h
- Ensemble of simulations: 41 models
  + 20 models with sensitive parameters

## Observational data

at point scale:

- snow depth measured (B3 and Teufelsegg)
- snow depth and SWE from snow profiles
  (B3, M4, and Lazaun)

B3 at 1990 m a.s.l.

M4 at 1998 m a.s.l.

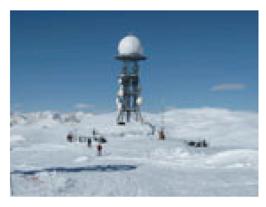
Lazaun at 2450 m a.s.l.

Teufelsegg (at 3035 m a.s.l.)

at catchment scale:

- snow-covered area (SCA) from EURAC MODIS (Moderate Resolution Imaging Spectroradiometer) Notarnicola et al. 2013
- Daily composite of Terra and Aqua product
- 250 m resolution
- Cloud corrected

Source: NASA

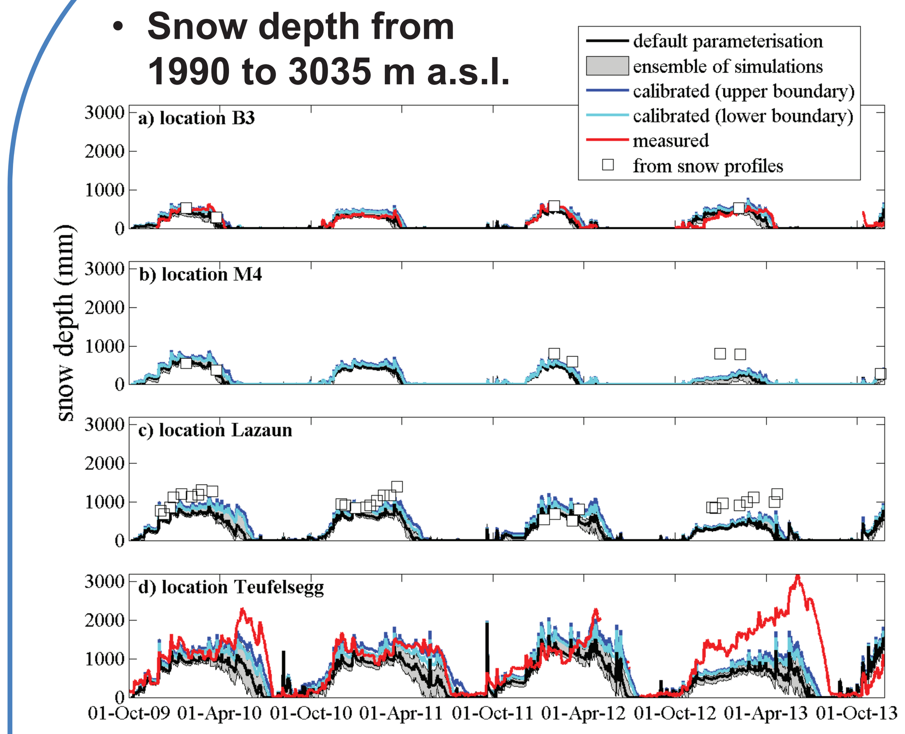


Source: www.eurac.edu

## Results

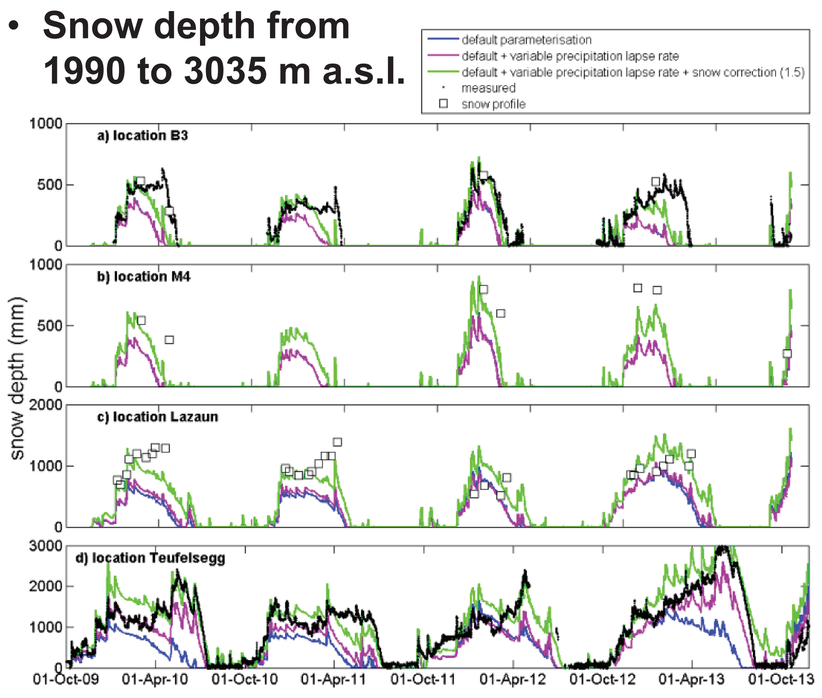
### Snow dynamics at the point scale

- **Snow depth from 1990 to 3035 m a.s.l.**

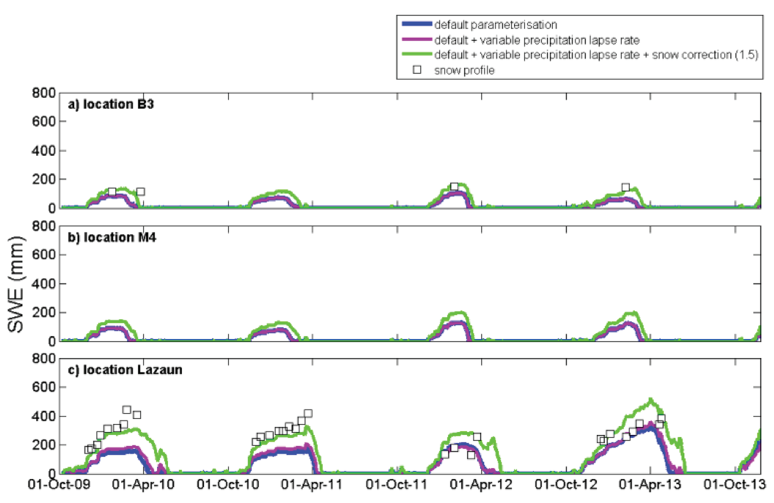



- Previous results from a manual sensitivity analysis show that snow depth and SWE is mainly governed by the model parameters controlling snow albedo, precipitation and water saturation in the snowpack.
- Typical weather conditions in periods with intense snowfall events as in Spring 2010 and 2013 are strongly underestimated at higher elevations.

- **Snow depth from 1990 to 3035 m a.s.l.**

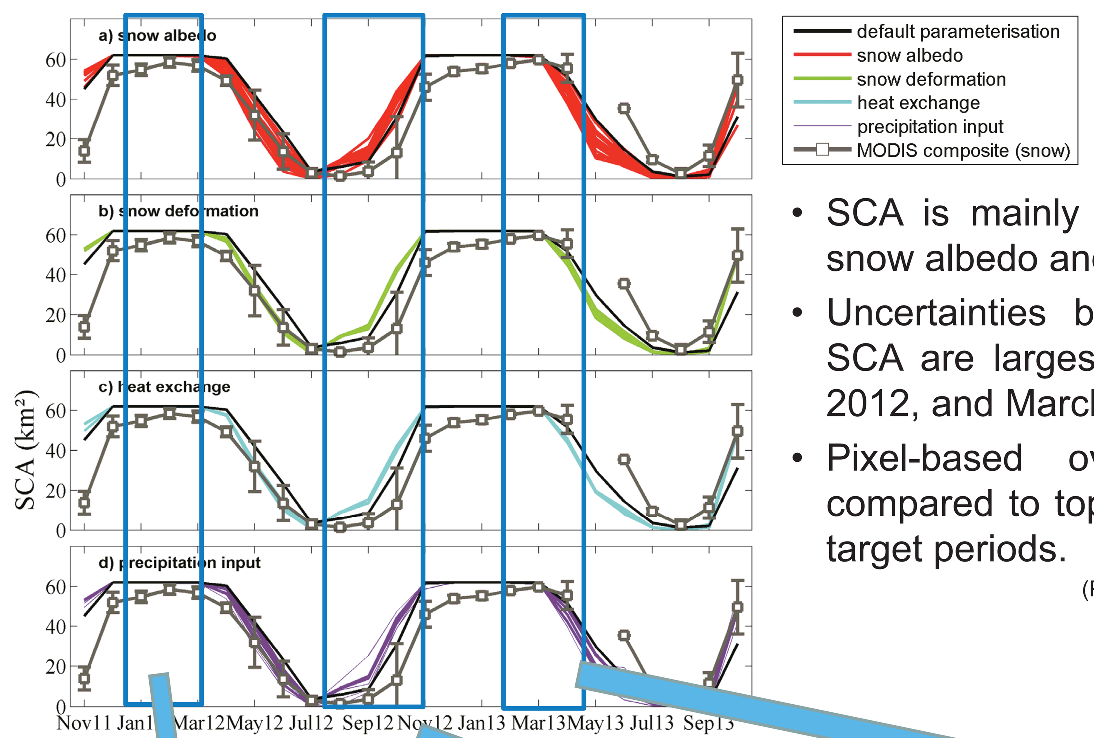



- **SWE from 1990 to 2450m a.s.l.**



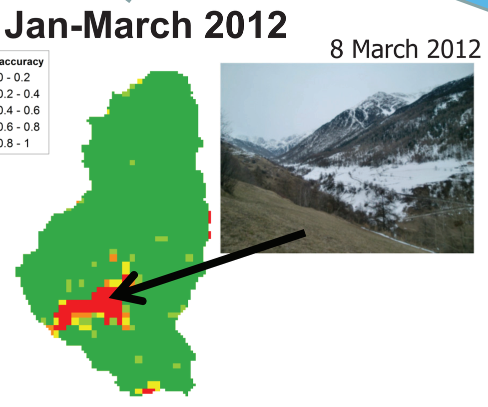

- Further results suggest that varying the lapse rates helps to match the interannual and event-based snow dynamics (p.e. in Spring 2010 and 2013).
- A better agreement between observed and simulated snow depth and SWE seems to be obtained in combination with increased fraction of solid precipitation.

### Snow dynamics at the catchment scale

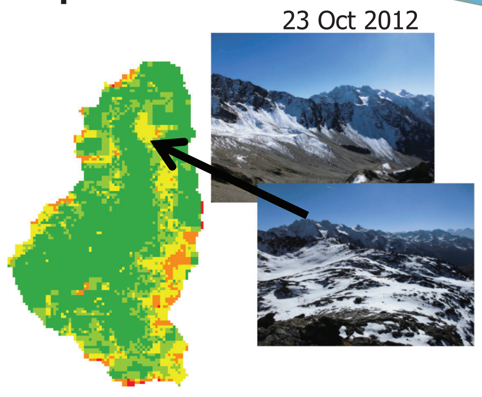



- SCA is mainly controlled by model parameters controlling snow albedo and precipitation.
- Uncertainties between simulated and observed (MODIS) SCA are largest in the periods Jan-March 2012, Sept-Nov 2012, and March-Jun 2013.
- Pixel-based overall accuracies were calculated and compared to topographical characteristics for these different target periods. (Parajka and Blöschl 2008)

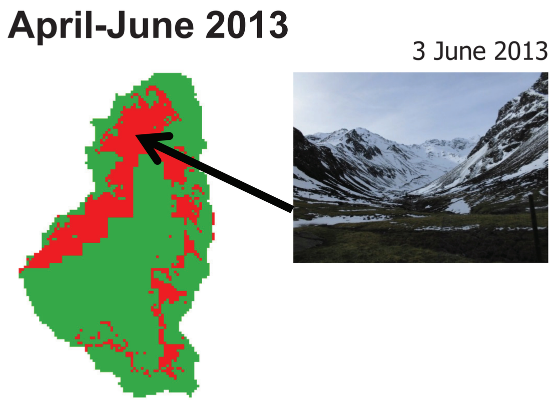
- **Jan-March 2012**

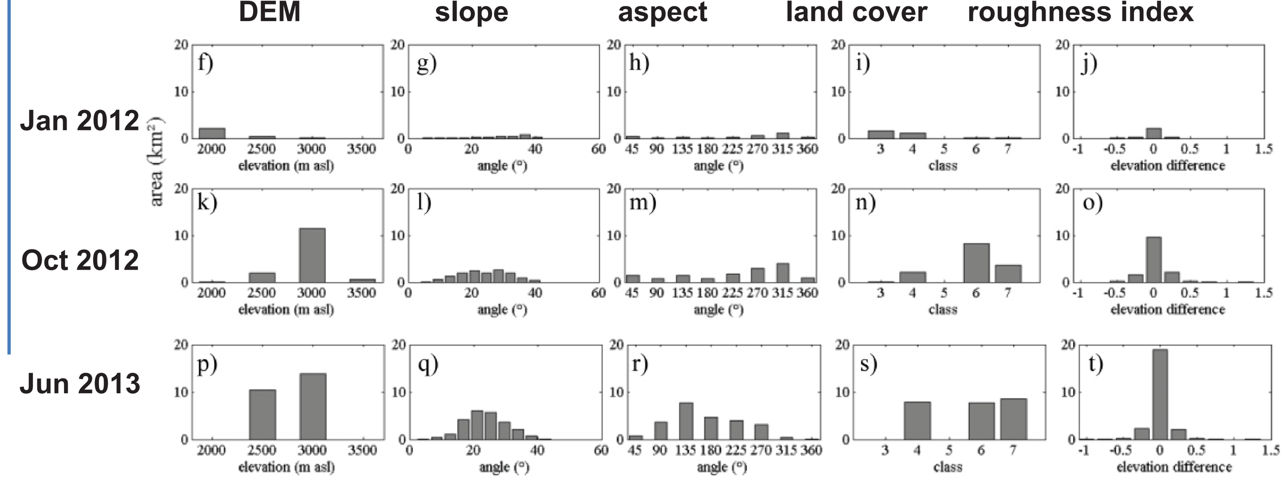



- **Sept-Nov 2012**




- **April-June 2013**




- Largest uncertainties in winter are associated with forested areas, where the MODIS product tend to underestimate SCA.
- In autumn major differences are associated with elevations between 2500-3000m a.s.l. covered by rocks with a high surface roughness indices between -0.25 and 0.
- Uncertainties in Spring 2013 could not be related to single topographical characteristics.

## Conclusions

- Modelling results of snow depth and SWE are in general good agreement with observed data both at point and catchment scale.
- In general, precipitation, snow albedo, and water saturation are found to be important snow controlling factors at both scales. Additionally, varying the precipitation lapse rate improves the point scale simulation of interannual and event-based snow dynamics. In a further step, this sensitivity needs to be tested at the catchment scale.
- Both model and MODIS inaccuracies at catchment scale are shown. Major differences are observed in forested areas in winter or rocky areas with increased surface roughness at higher elevations. However, Spring 2013 uncertainties can not be related to topographical characteristics but may result from uncertainties in simulated meteorological conditions.

## Acknowledgment

The Herzog-Sellenberg- and Dr. Erich Ritter-Stiftung within the Stifterverband für die Deutsche Wissenschaft financed the EMERGE project. The Free University of Bozen-Bolzano funded the project "Effects of climate change on high-altitude ecosystems: monitoring the upper Matsch Valley".

The Hydrographic Office of Bozen provided meteorological data. MODIS data were preprocessed by Roberto Monsorno & Bartolomeo Ventura.

Contact: Michael.Engel@unibz.it