A terrain-based parameterization for the effect of wind-induced snow transport in Alpine terrain

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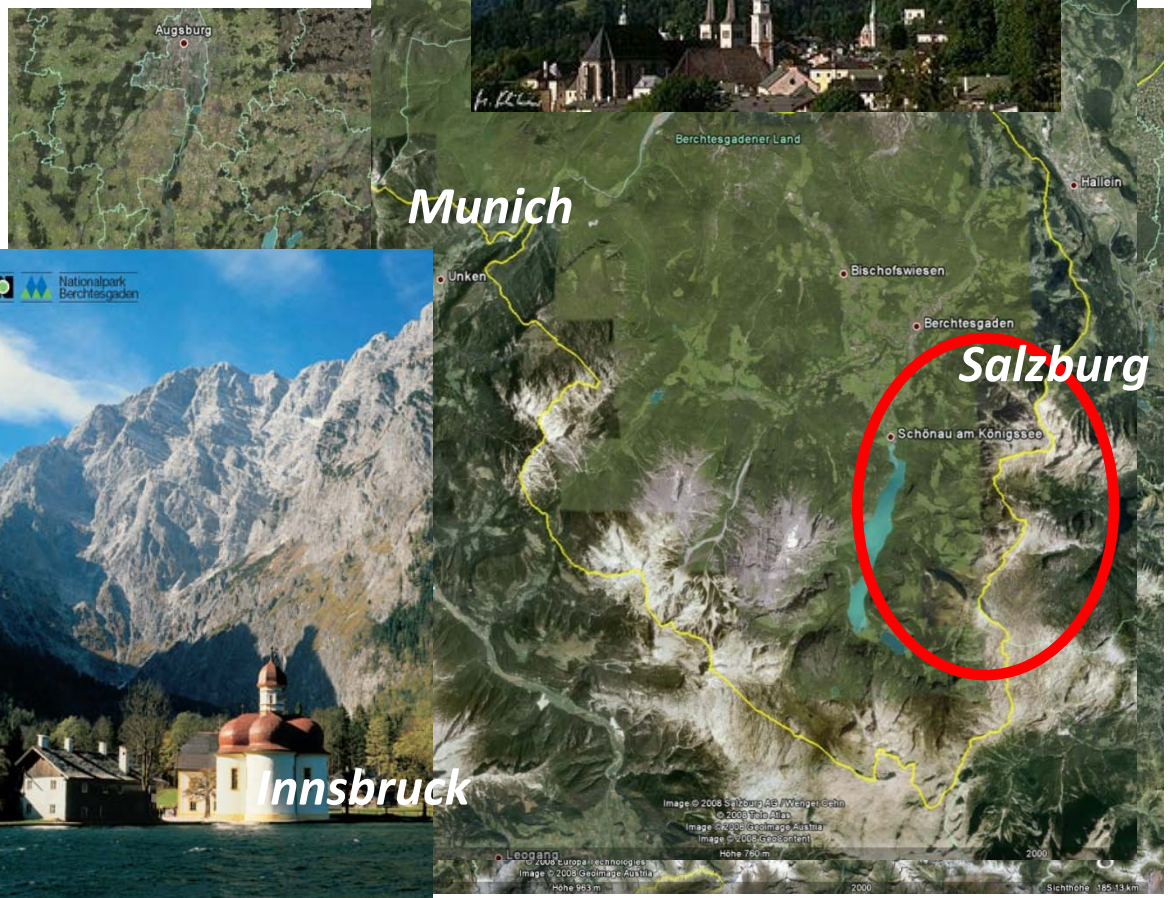
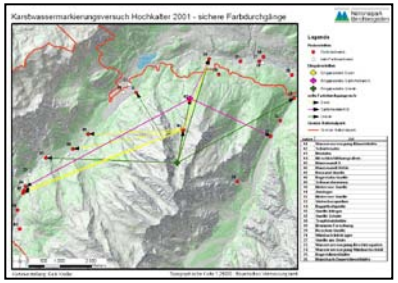
Karlsruhe Institute of Technology (KIT), Institute for Meteorology and Climate Research (IMK-IFU)

Berchtesgaden National Park





Surface and Subsurfcace Hydrology

- Steep gradients
- Complex hydrogeological situation
- Karst, Subsurface pathways, Storage system

→ “Alpine karst and its influence on the water balance at regional scale. “
Kraller et al. **(Poster Programme HS2.5, A 240, EGU2011-2229)**

Snow cover dynamics

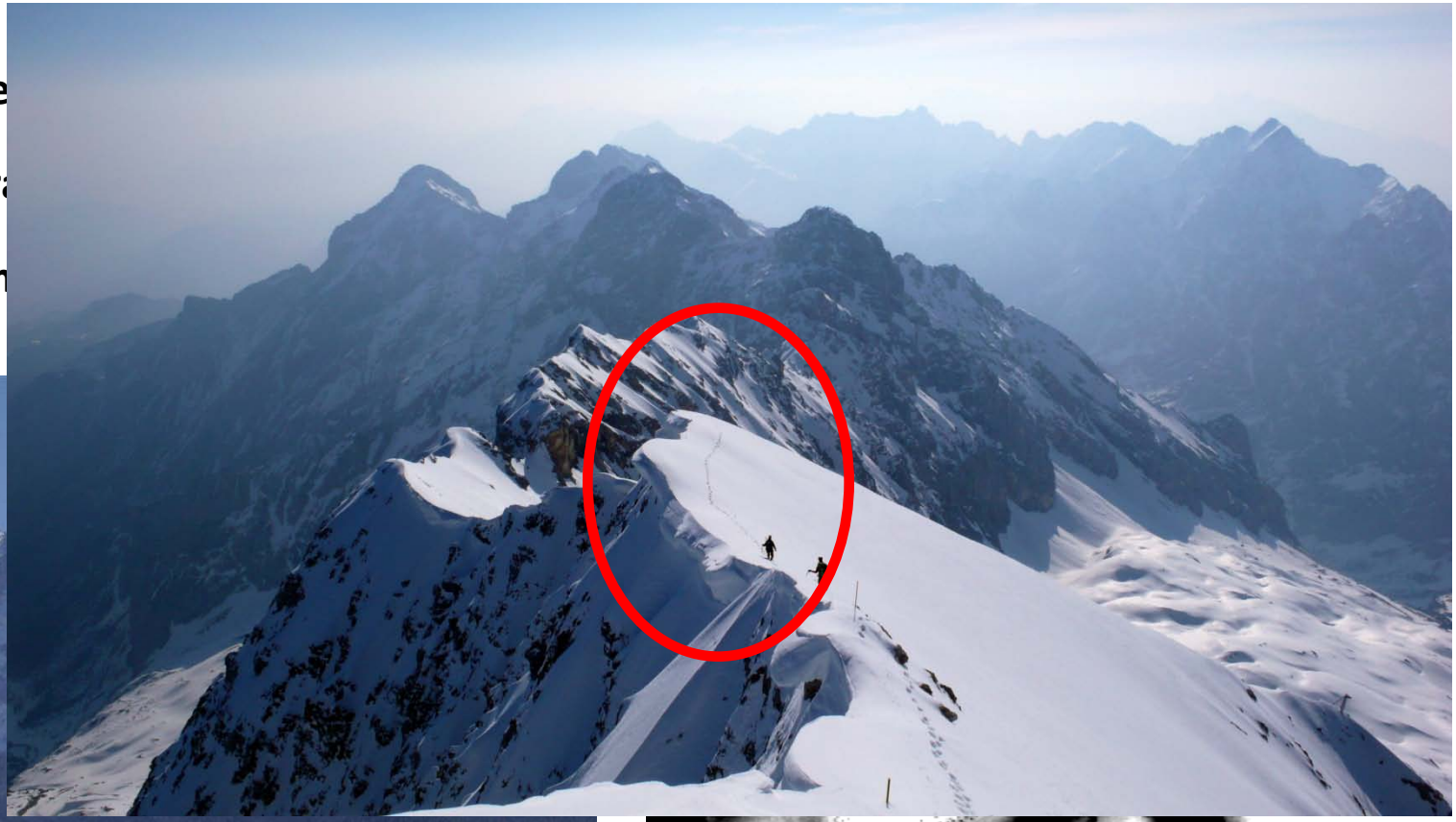
- Large amounts of snow, long period of snow coverage
- Spatial and temporal variability of the snow cover
- Precipitation storage during winter, runoff generation by melting snow
- Snow „feeds“ glaciers and perennial firn fields
- Lateral snow transport (**wind**, snow slides, avalanches)

Processes:

1. **Preferential de**

2. Wind-driven **tra**

3. Effective **sublim**



Plattner (2004)

Methods

Bernhardt et al. (2009): *Using wind fields from a high-resolution **atmospheric model** for simulating snow dynamics in mountainous terrain*

Winstral and Marks (2002): *Simulating wind fields and snow redistribution using **terrain-based parameters** to model snow accumulation and melt over a semi-arid mountain catchment*

Snow and wind

Approach:
modified, Winstral and Marks (2002)

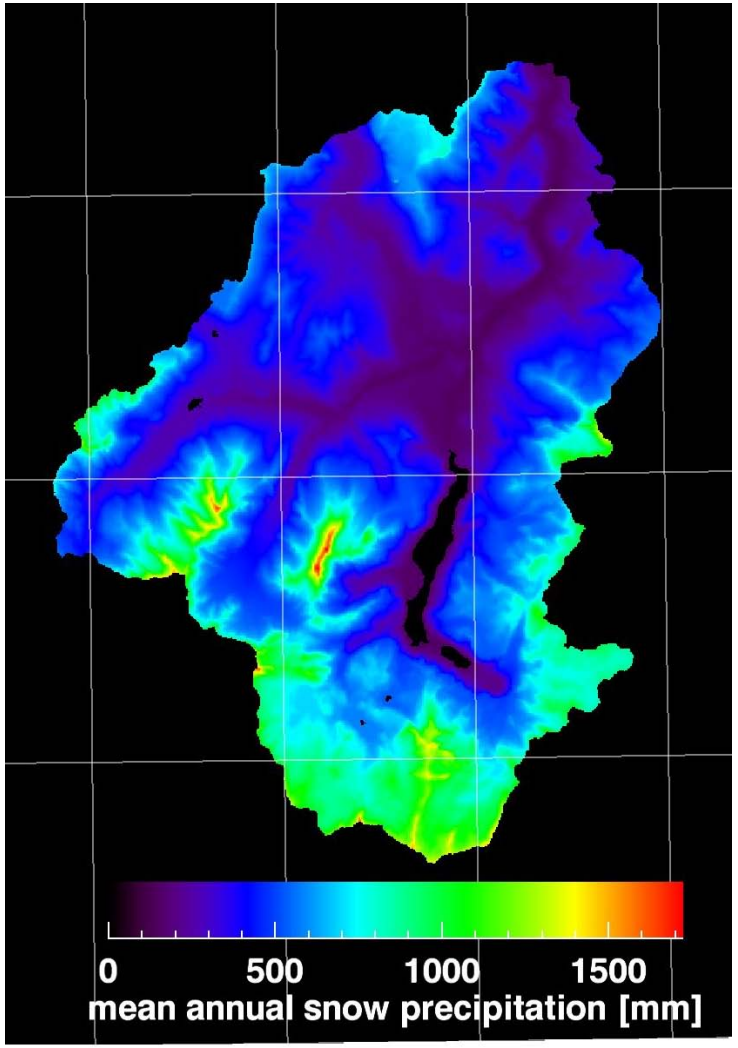
- Terrain-analysis to extract sheltered and exposed areas

- **Sheltered pixel → accumulation of wind-blown snow**, more snow

- **Exposed pixel → erosion of snow**, less snow

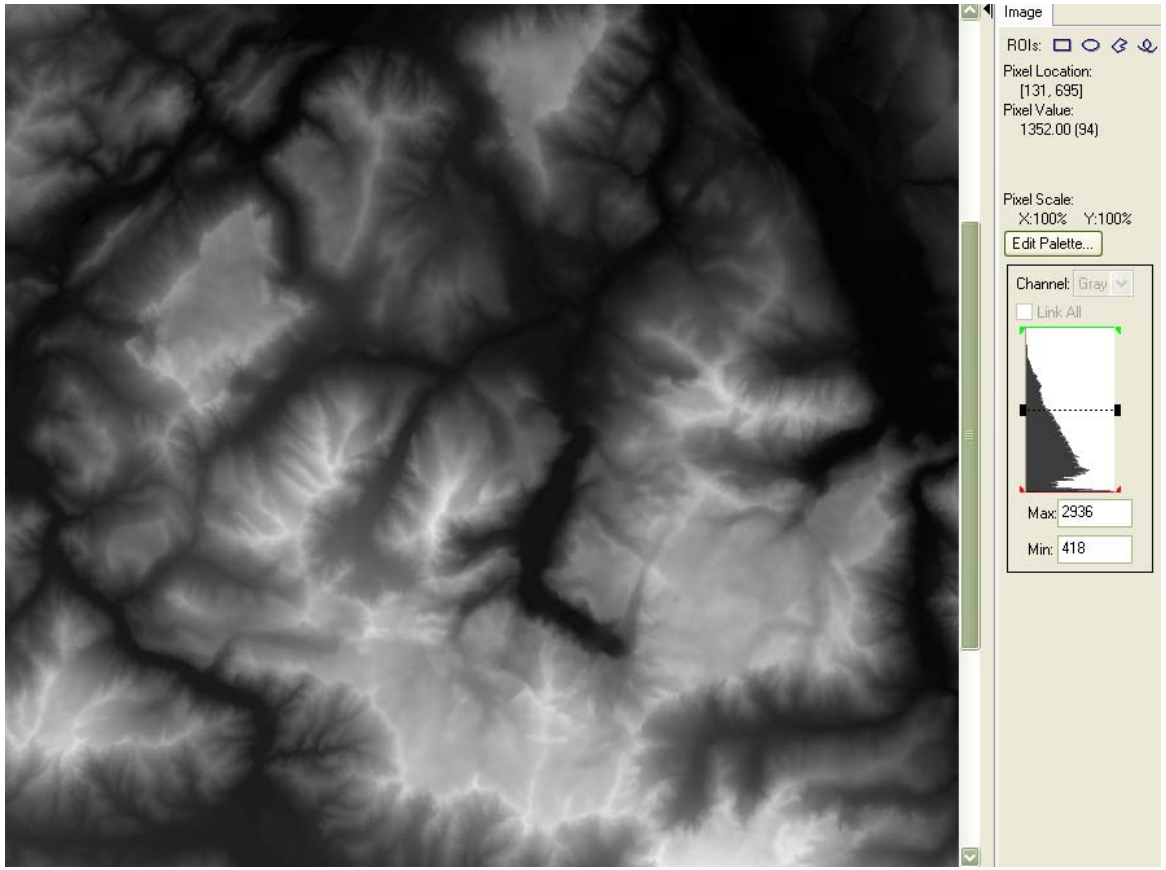
- **Correction of snow precipitation** in advance

- Result represents the **combination of all wind-driven snow effects** (preferential deposition, erosion, saltation, suspension, accumulation, sublimation)

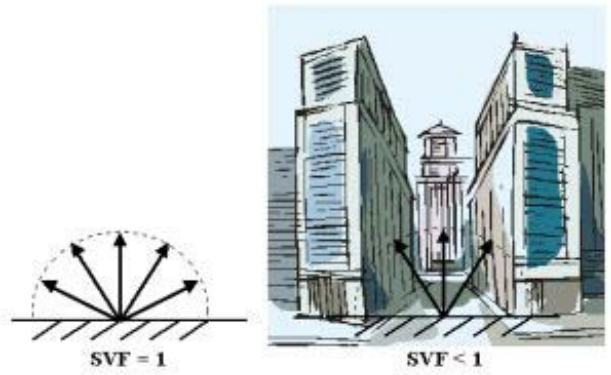


Terrain analysis

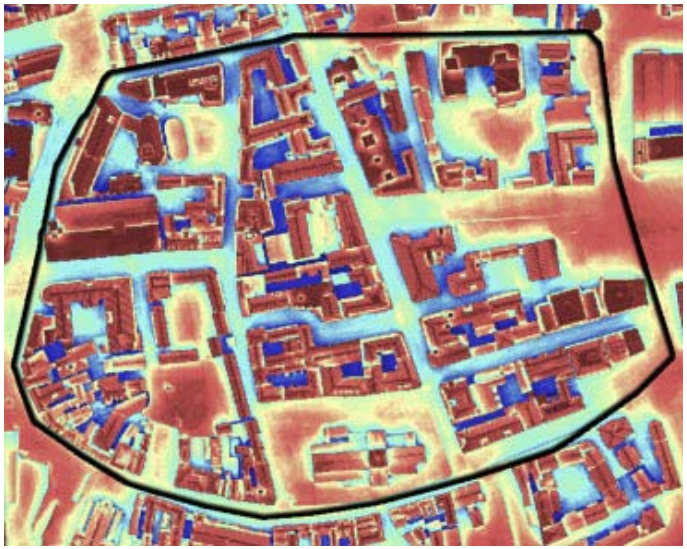
- Extraction of a factor image from the digital elevation model (DEM)
- Partial, directed **sky view factor (SVF_{dir})**



Sky view factor



espere, Wypych (nach Oke, 1987)
http://www.atmosphere.mpg.de/enid/2__Stadtklima/-_Bestimmende_Faktoren_41q.html

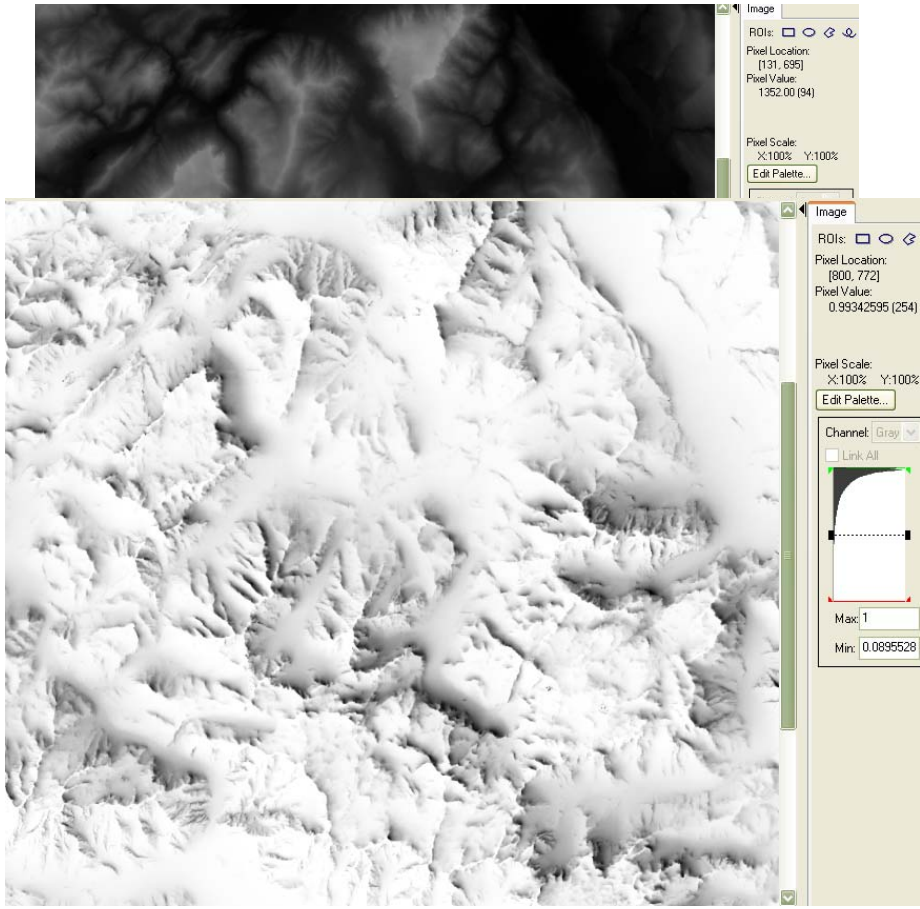


http://www.carltd.com/feature33.htm

University of Gothenburg
http://www.gvc2.gu.se/ngeo/urban/Activities/svf.htm

Terrain analysis

- Extraction of a factor image from the digital elevation model (DEM)
- Partial, directed **Sky View Factor (SVF_{dir})**
- Defininition of wind direction sector (e.g. SW, 180° - 270 °)
- → **directed sky view factor SVF_{dir}**

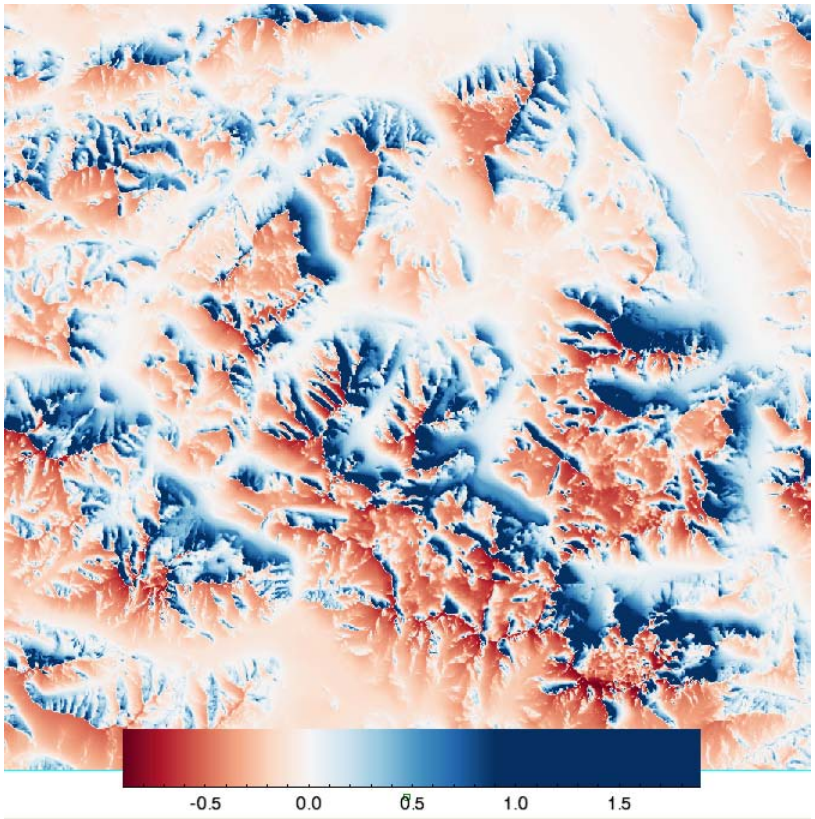


$$windCorrField = E * (Dep_{max} * (1 - SVF_{dir}) - 1) + 0.1$$

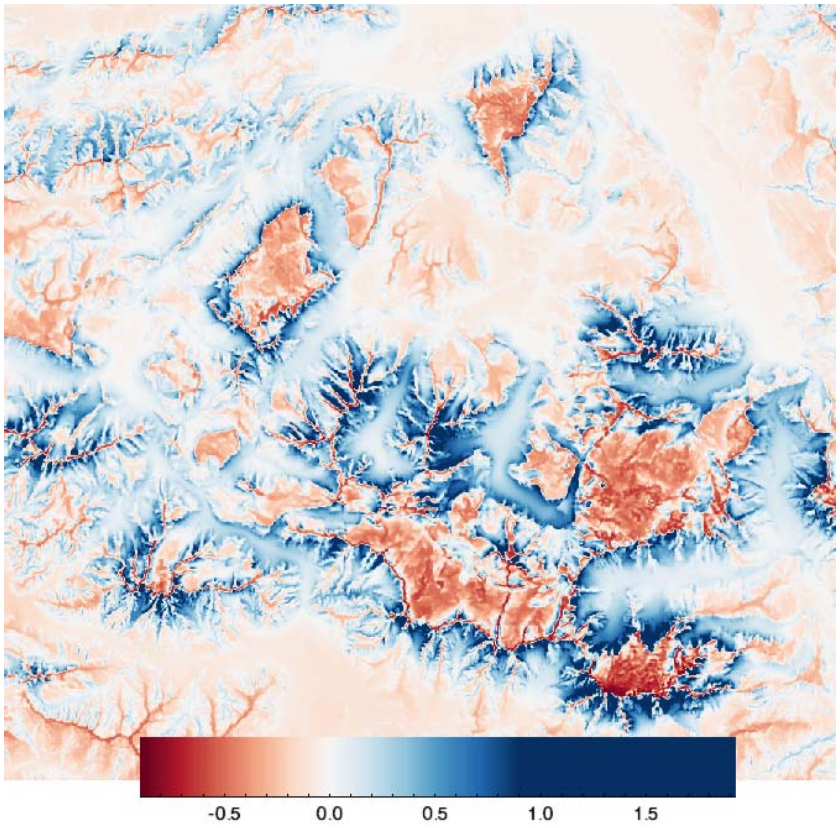
where

E = (linear) elevation weighting factor
SVF_{dir} = directed sky view factor
Dep_{max} = maximum possible deposition

Wind direction: SW

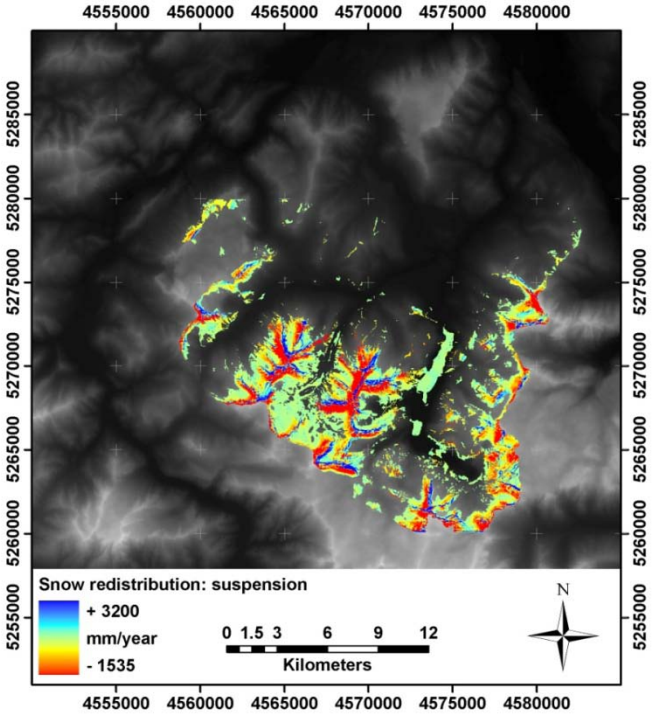


No prevailing wind direction

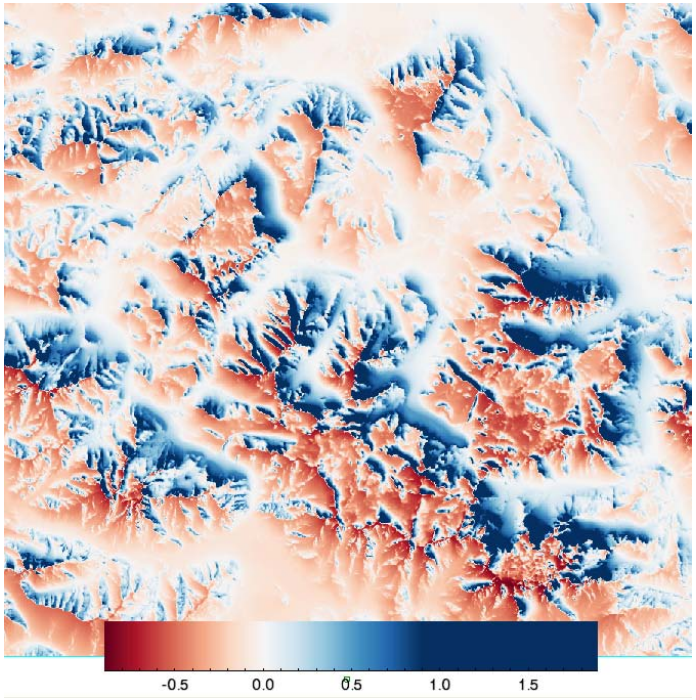


Snow and wind

Coupled atmospheric / snow transport model



Parameterization (wind direction SW)



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BERNHARDT, M., ZÄNGL, G., LISTON, G. E., STRASSER, U. AND MAUSER, W. (2009): *Using wind fields from a high-resolution atmospheric model for simulating snow dynamics in mountainous terrain.* Hydrological Processes, 23: 1064–1075. doi: 10.1002/hyp.7208

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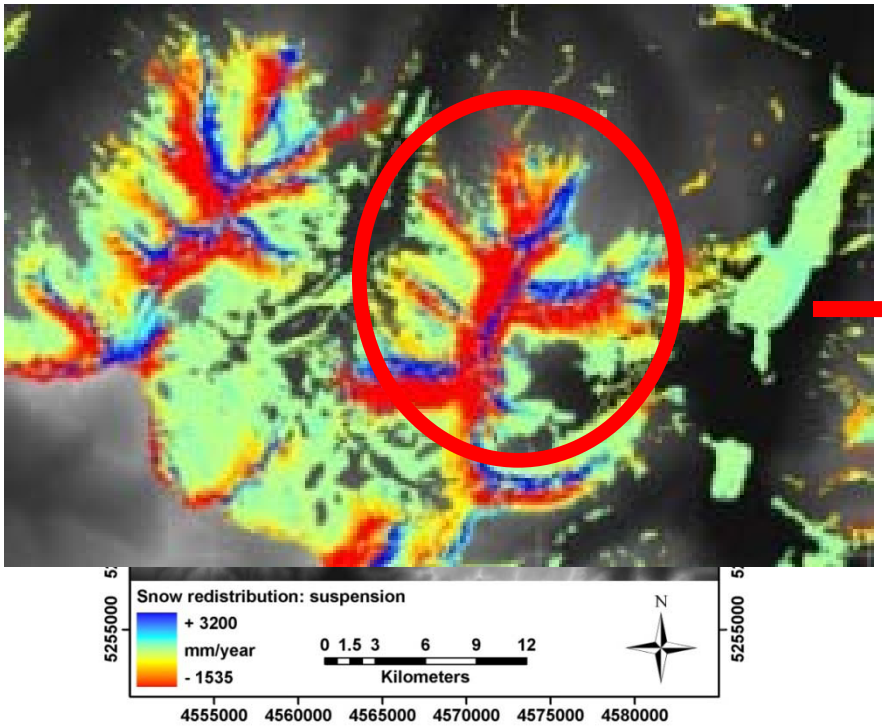

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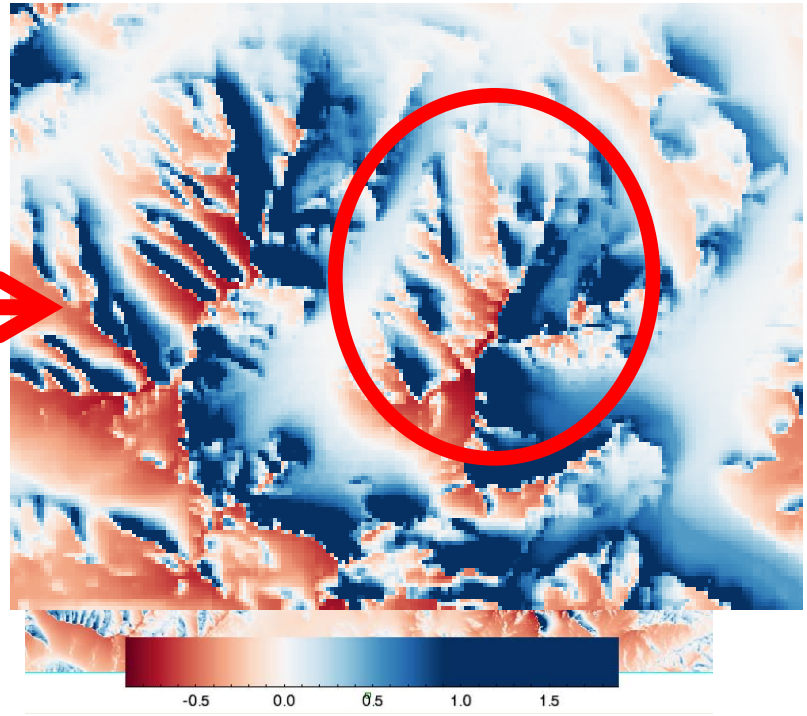

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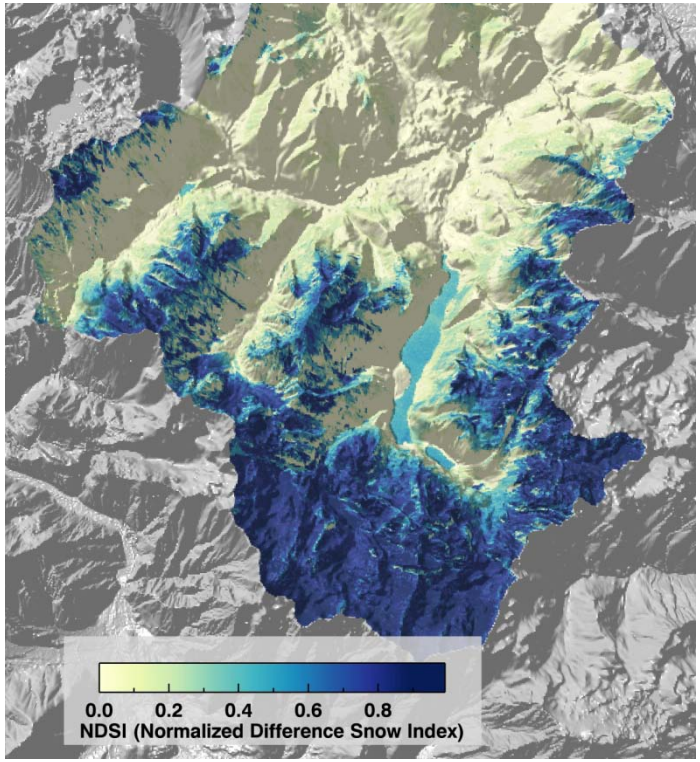
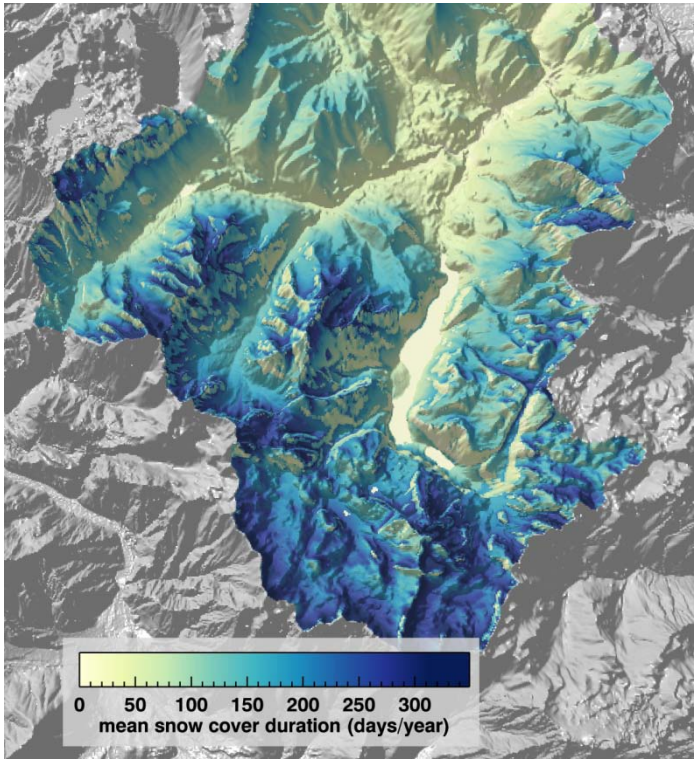
→ Similar spatial patterns

Landsat RGB ETM+
01.05.2005



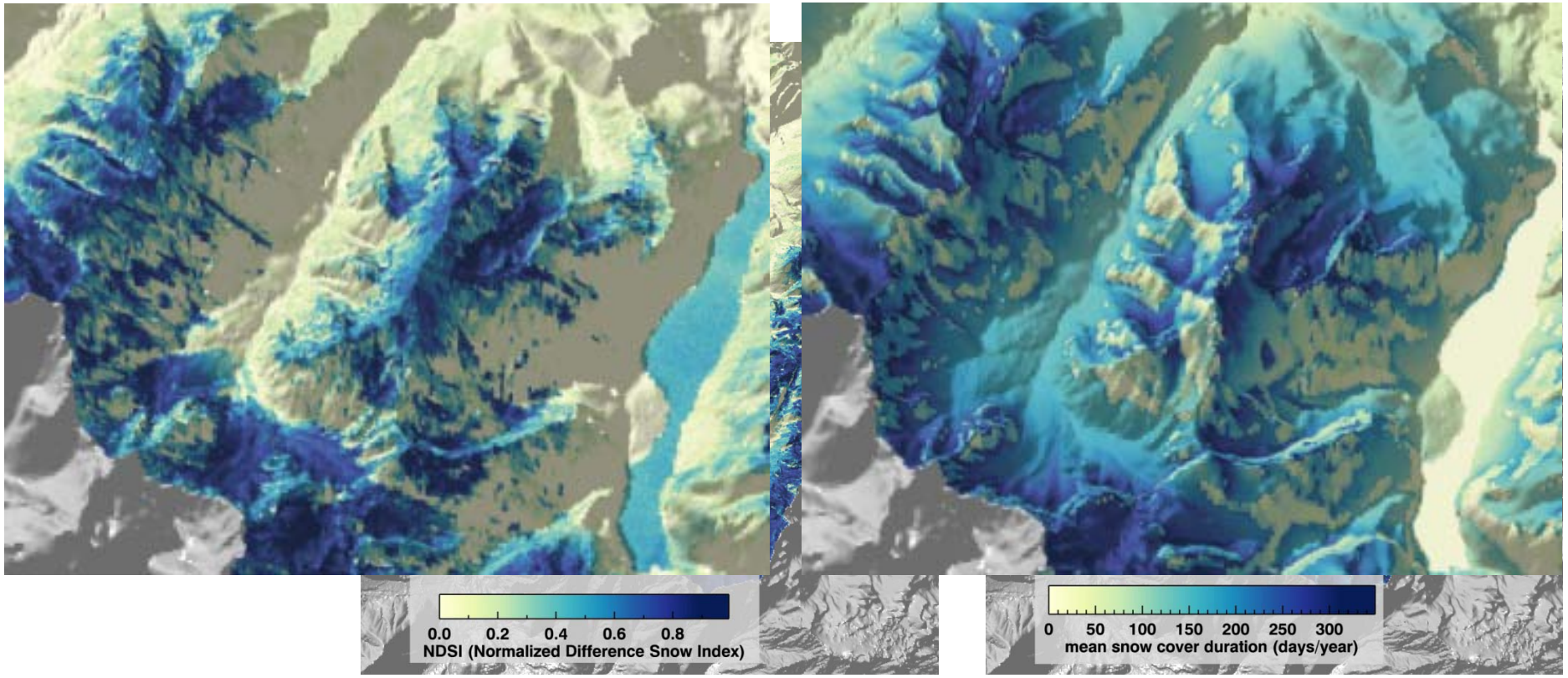
NDSI (not showing negative values)
01.05.2005



Modelled mean snow cover duration
2002 – 2007

Landsat ETM+

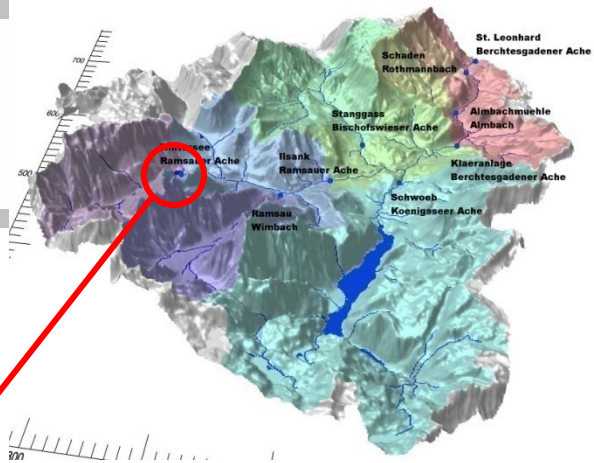
Model (WaSiM-ETH + AMUNDSEN)



NDSI (not showing negative values) 01.05.2005

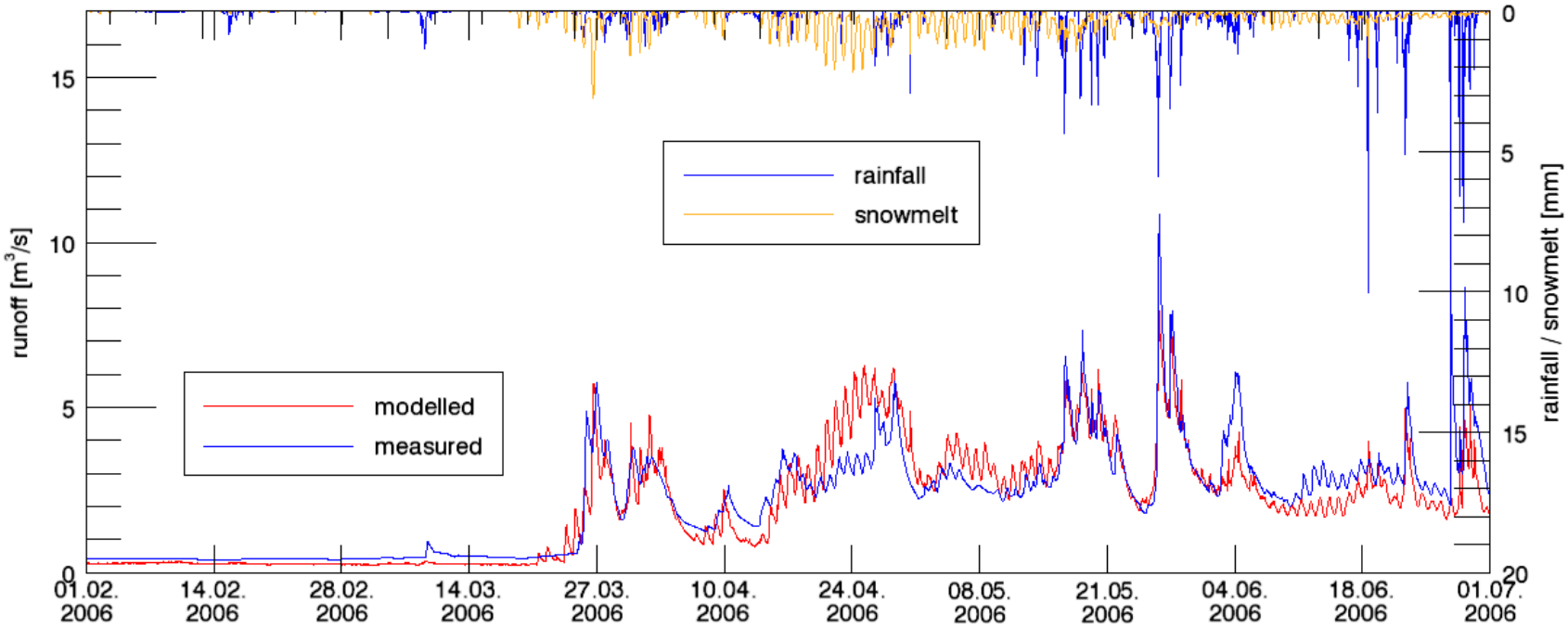
Modelled mean snow cover duration 2002 – 2007

Snow melt and runoff dynamics



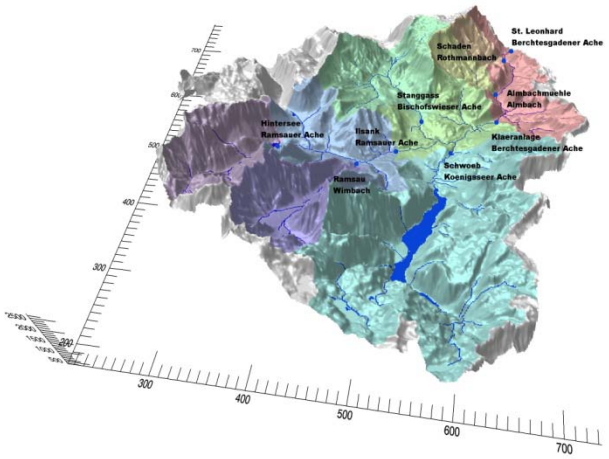
Do we need that within hydrological LSMs?

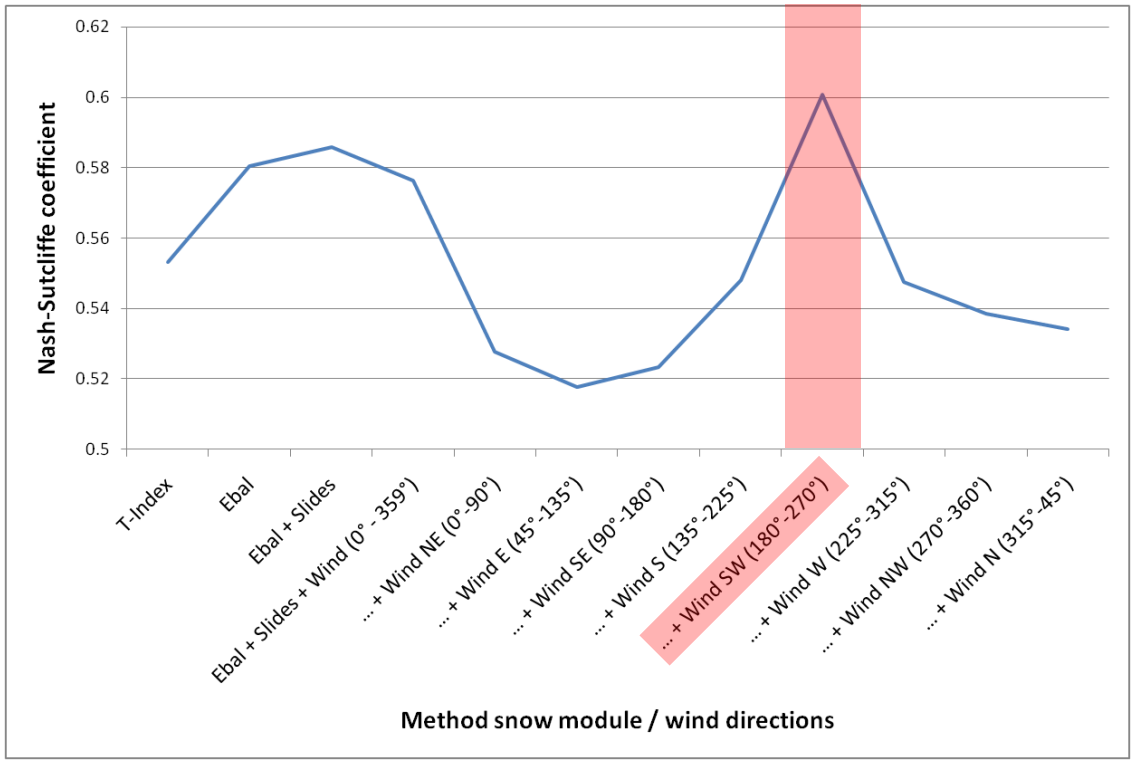
Runoff at gauge Hintersee (melting period spring 2006)



Snow module:	**Day-Degree**	**E-Bal + Snowslides**	**E-Bal + Snowslides + Wind**
	Nash-Sutcliffe = 0.52	**Nash-Sutcliffe = 0.69**	**Nash-Sutcliffe = 0.76**

Do we need that within hydrological LSMs?





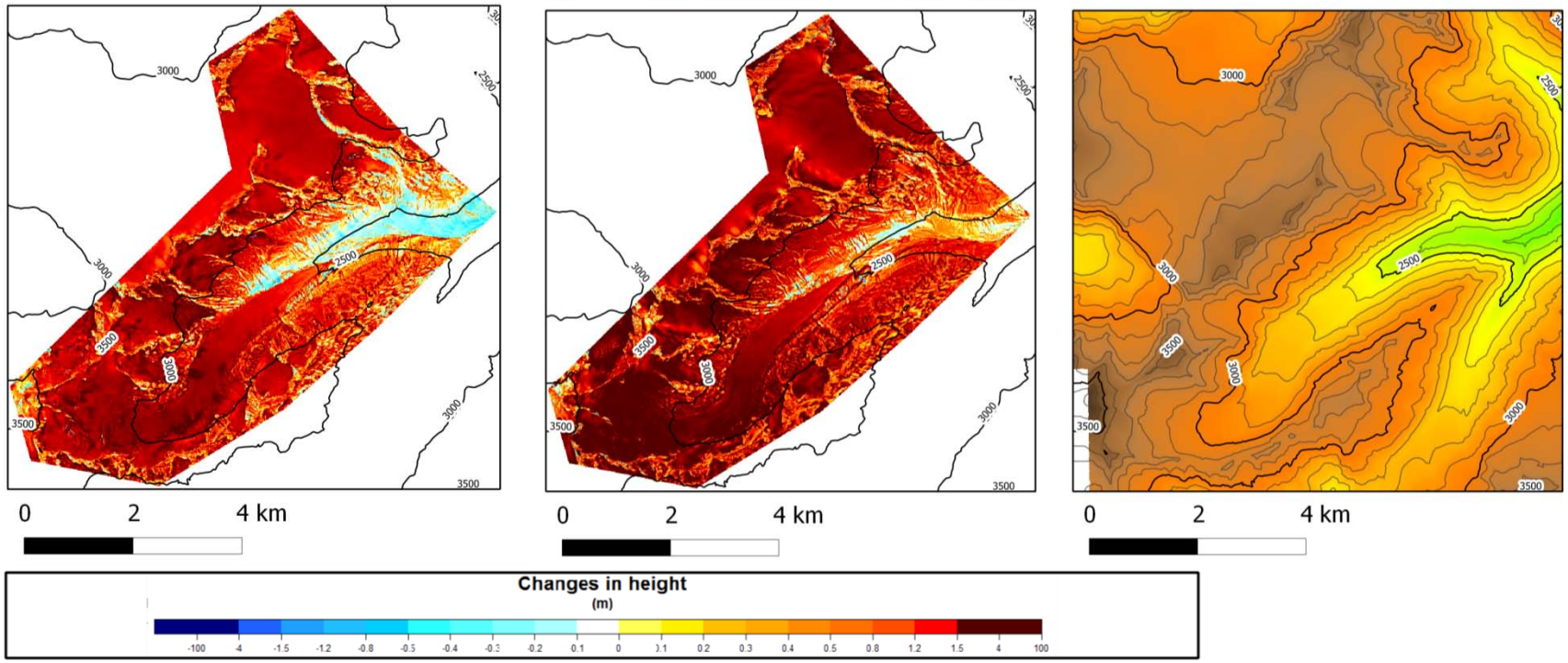
Overall model performance: Mean Nash-Sutcliffe coefficient at the gauges (Nov. 2002 – Okt. 2007) with different snow model approaches and different assumed main wind direction sectors

Airborne Laserscanning data

Changes in height

May 2003 minus September 2002

May 2009 minus September 2008



Hintereisferner

Thanks!