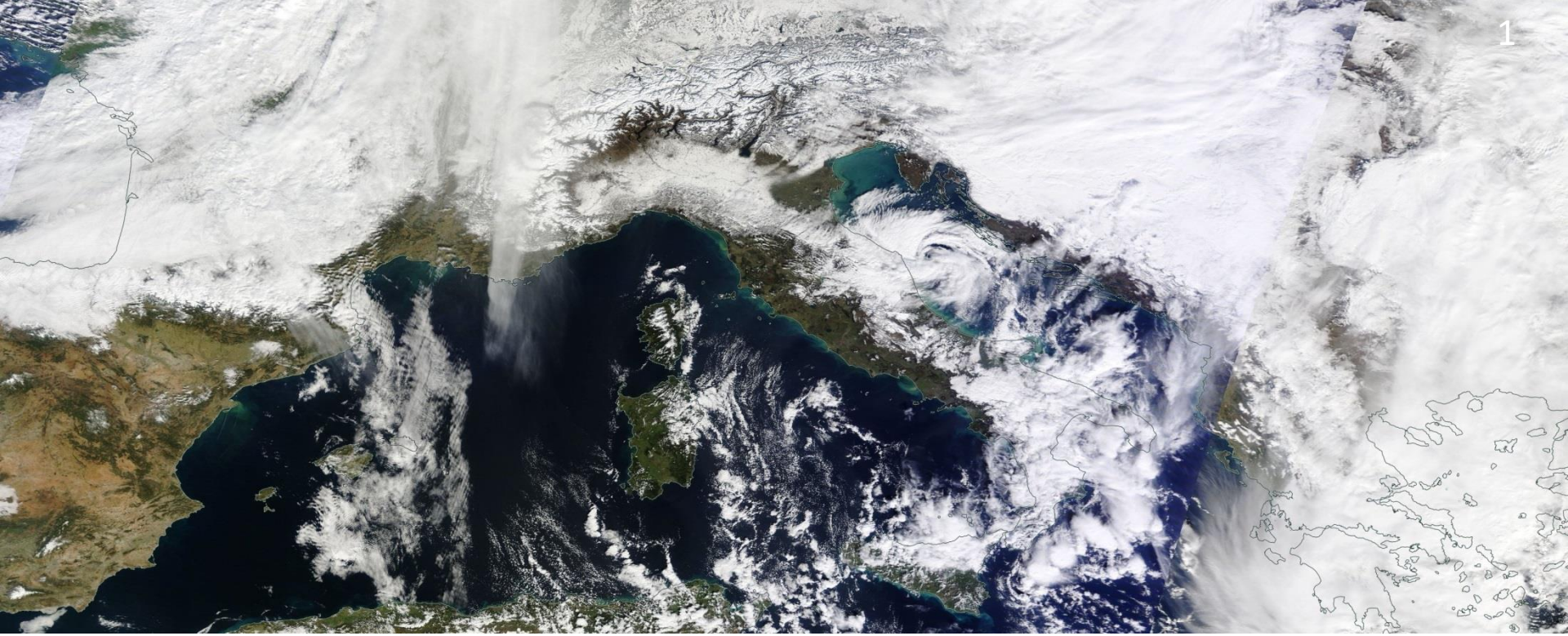


About the use of snow satellite products in hydrological modelling

Carlo De Michele
carlo.demichele@polimi.it

POLITECNICO
MILANO 1863

Here I will use

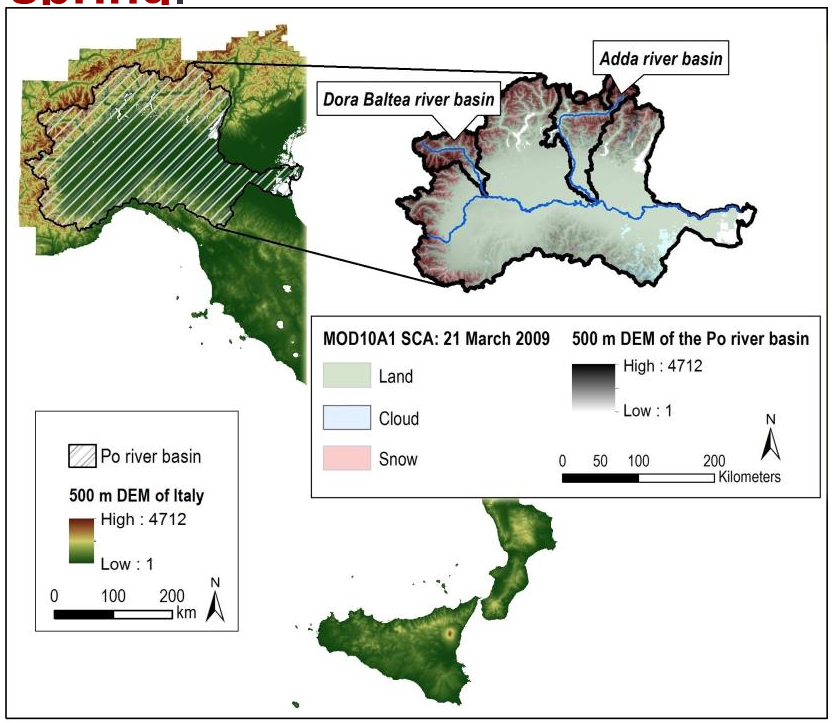
- **MODIS (Terra and Aqua) products**;
- **Snow cover and cloud cover products (MOD10A1/ MYD10A1)**

Outline

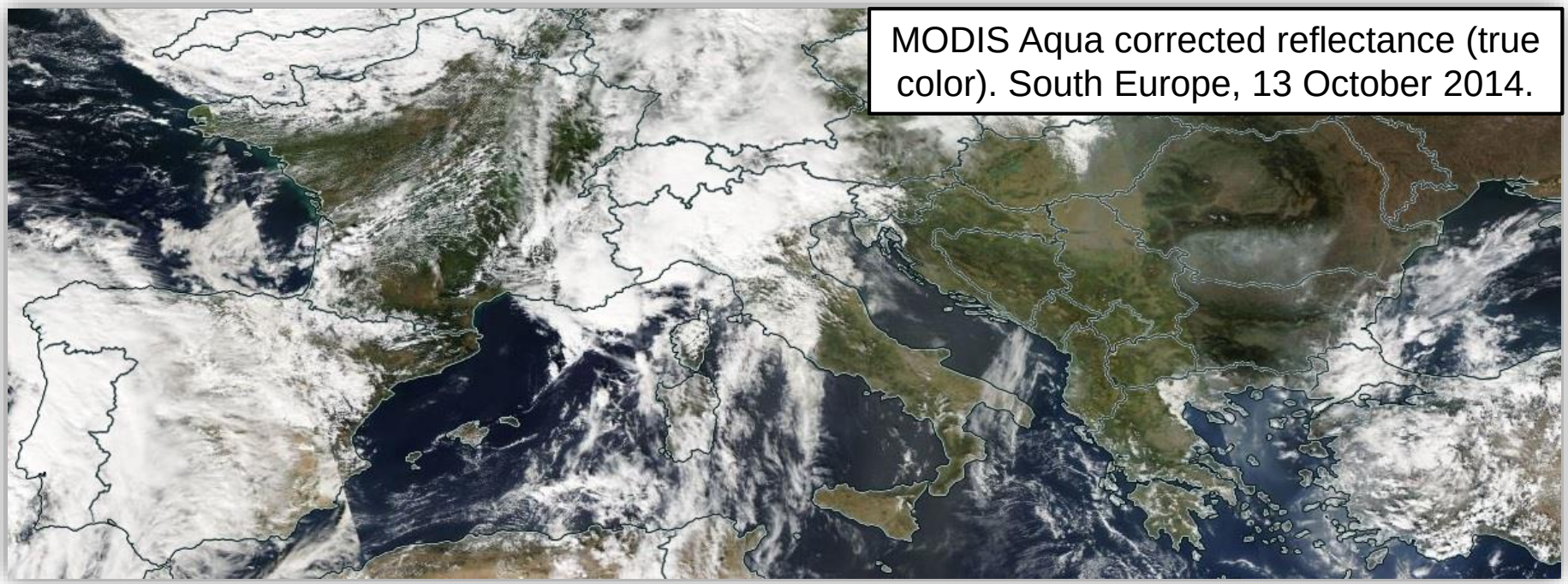
- **Use** of snow cover maps to check the performance of Regional Climate Models;
- **Use** of snow cover maps to provide inputs/constraint to Hydrological Models;
- **Use** of snow cover maps to investigate impact of topographic controls.

Case study: Po river basin

- Po is the **major Italian river** and one of the most important fluvial system in Europe (drainage area ~ 74 · 10^3 km^2).
- **More than 30%** of the area lies above **1000 m asl.** In the Alpine valleys, snow is a **key element** also for water management, winter tourism and for its role in the ecosystem.
- The percentage **SCA** ranges from a stationary percentage **> 30% in winter** to ~ **5% in spring**.

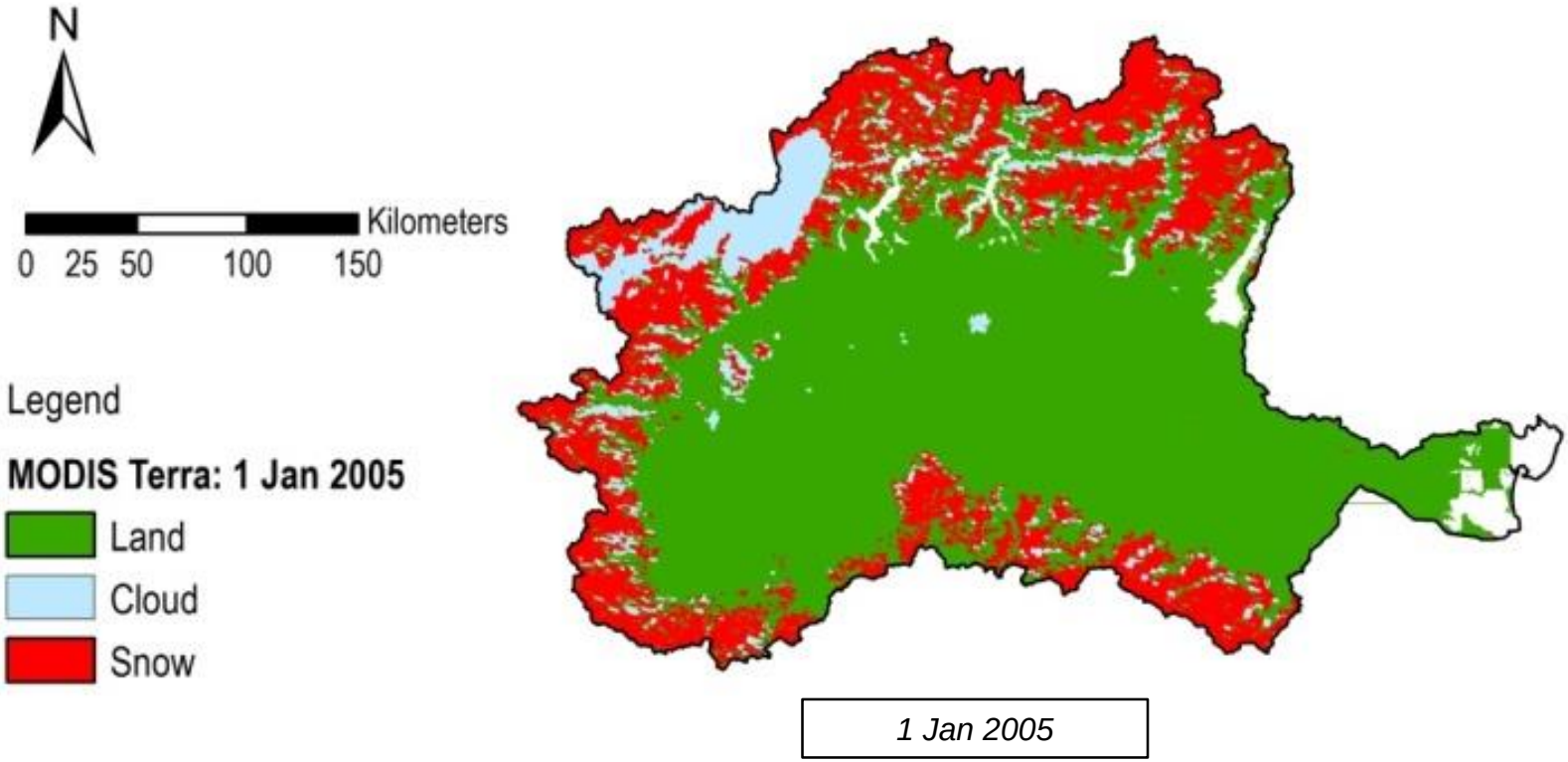


The issue of cloud obstruction in assessing snow cover



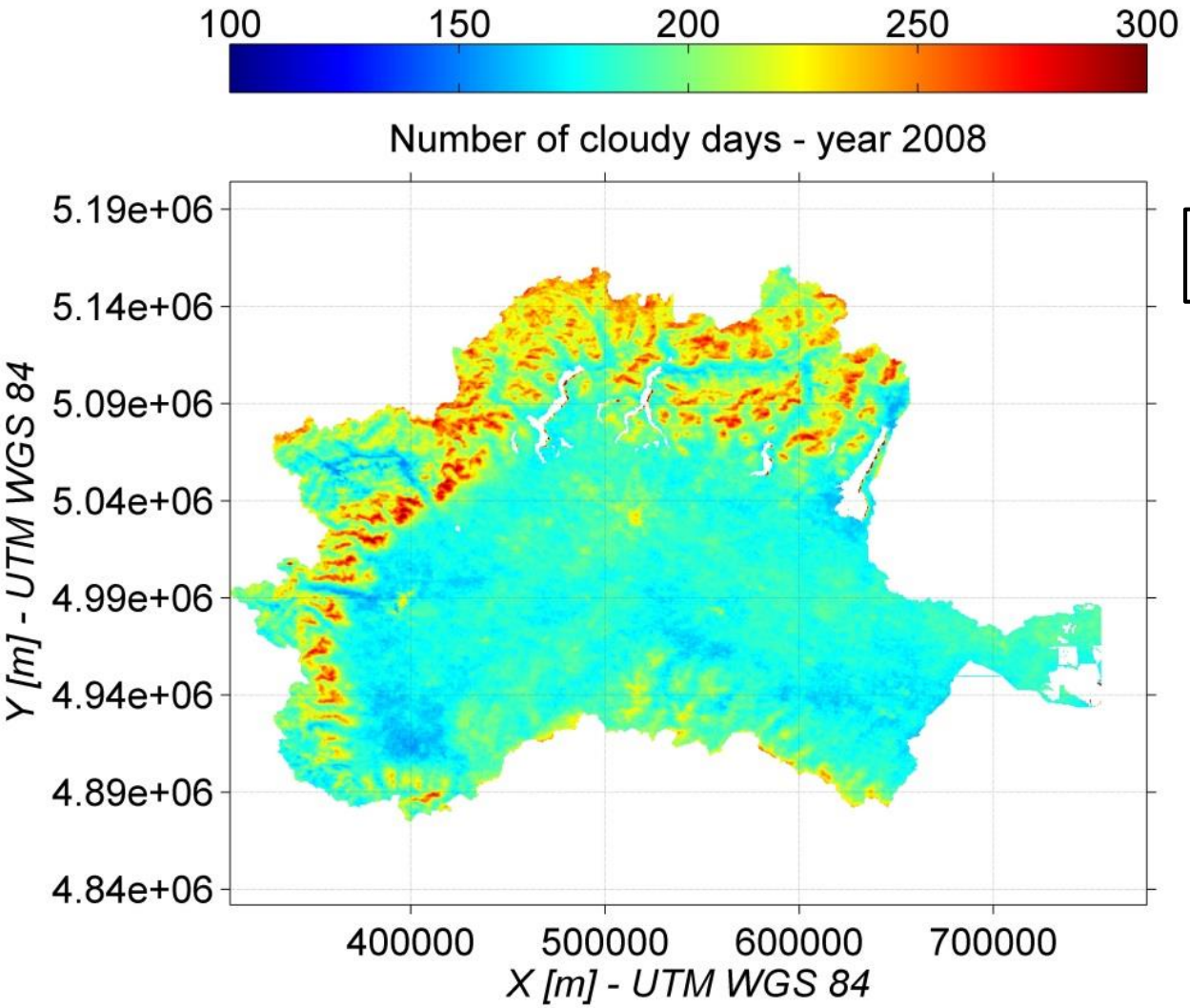
MODIS Aqua corrected reflectance (true color). South Europe, 13 October 2014.

Cloud cover frequency in the Po river basin



1 Jan 2005

Cloud cover frequency in the Po river basin



2008

Cloud obstruction over Po river basin

Year	J F M	A M J	J A S	O N D
2003	0.47	0.64	0.41	0.59
2004	0.60	0.68	0.52	0.61
2005	0.50	0.61	0.55	0.51
2006	0.54	0.68	0.52	0.45
2007	0.61	0.66	0.44	0.46
2008	0.51	0.77	0.50	0.60
2009	0.54	0.67	0.46	0.57
2010	0.64	0.72	0.47	0.62
2011	0.54	0.64	0.45	0.46
2012	0.50	0.71	0.48	0.59

In spring higher is the percentage of cloudiness!

A cloud removal procedure

Hydrol. Earth Syst. Sci., 18, 1–22, 2014
www.hydrol-earth-syst-sci.net/18/1/2014/
doi:10.5194/hess-18-1-2014

Hydrology and Earth System Sciences
Open Access

Cloud obstruction and snow cover in Alpine areas from MODIS products

P. Da Ronco[1,2] and C. De Michele[2]

[1]Centro Euro-Mediterraneo sui Cambiamenti Climatici, Impacts on Soil and Coasts Division, Capua, CE, Italy
[2]Politecnico di Milano, Department of Civil and Environmental Engineering, Milano, Italy

Step 1 **Merging Aqua/Terra images**

↓

Step 2 **Conservative temporal filter**

↓

Step 3 **Regional snow line approach**

↓

Step 4 **Backward temporal filter**

↓

Step 5 **Seasonal filter**

1) Use of snow cover maps to check the performance of Regional Climate Models

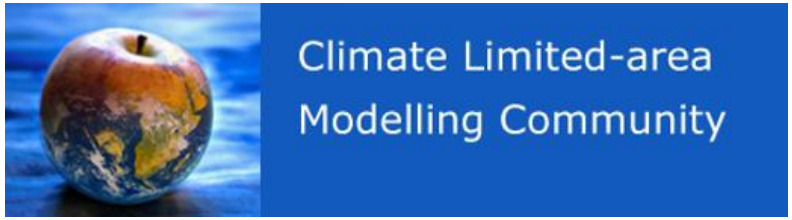
Clim Dyn
DOI 10.1007/s00382-016-3054-2

CrossMark

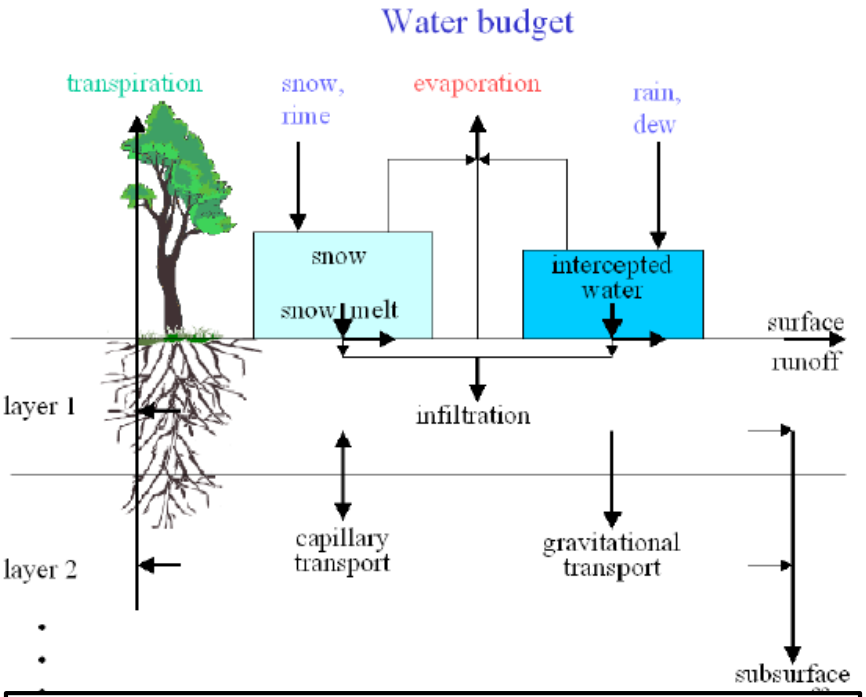
Comparing COSMO-CLM simulations and MODIS data of snow cover extent and distribution over Italian Alps

Pierfrancesco Da Ronco[1,2] · Carlo De Michele[1] · Myriam Montesarchio[2,3] · Paola Mercogliano[2,3]

- **COSMO-CLM** is a **regional model** developed by the CLM Community.



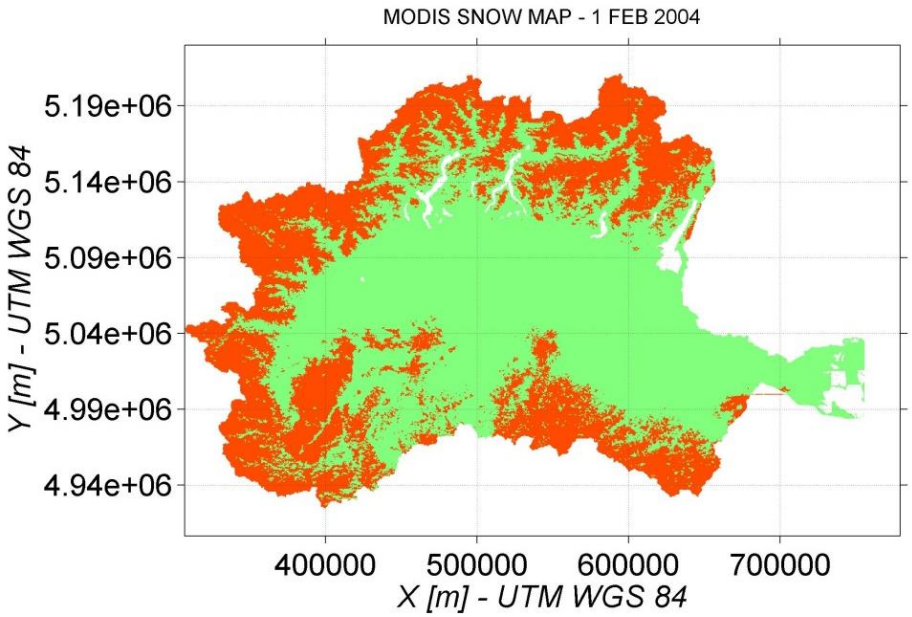
- Land-surface interactions in COSMO-CLM are modeled by the **soil model TERRA ML.**

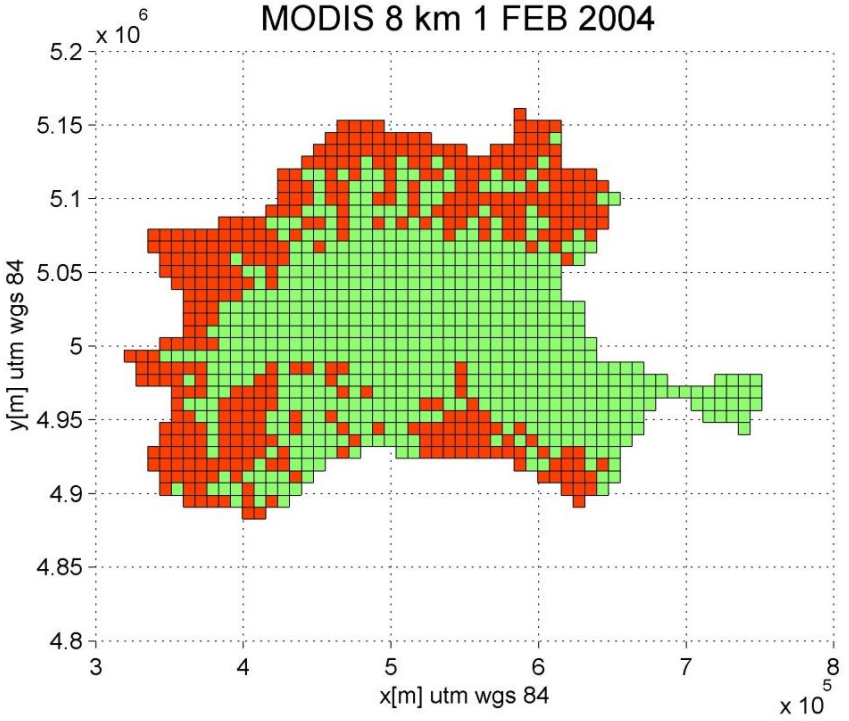


Terra_LM water budget (by Doms et al., 2011)

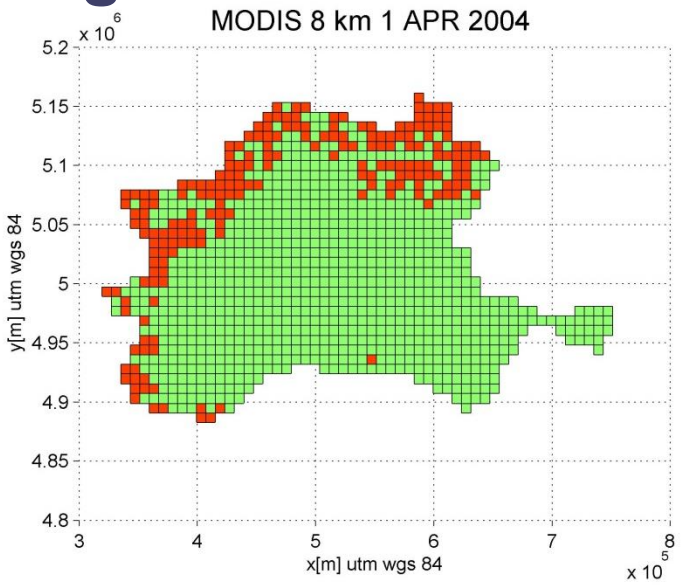
1) Use of snow cover maps to check the performance of Regional Climate Models

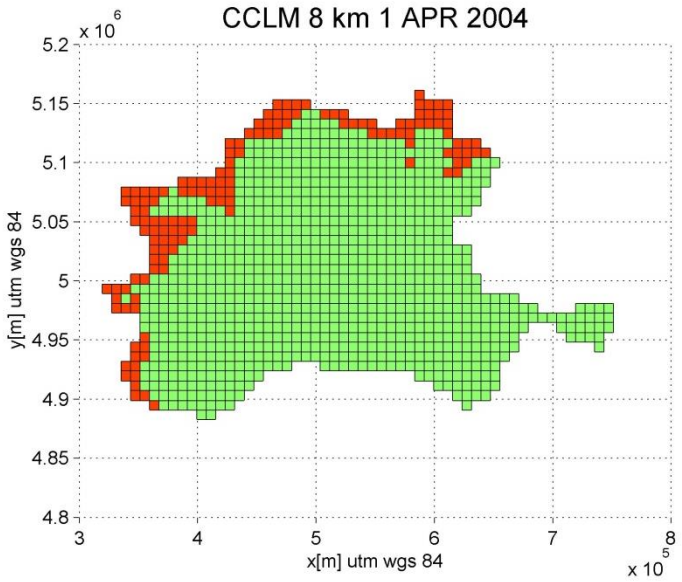
MODIS NEAREST NEIGHBOR RESAMPLING 500 m TO 8 km

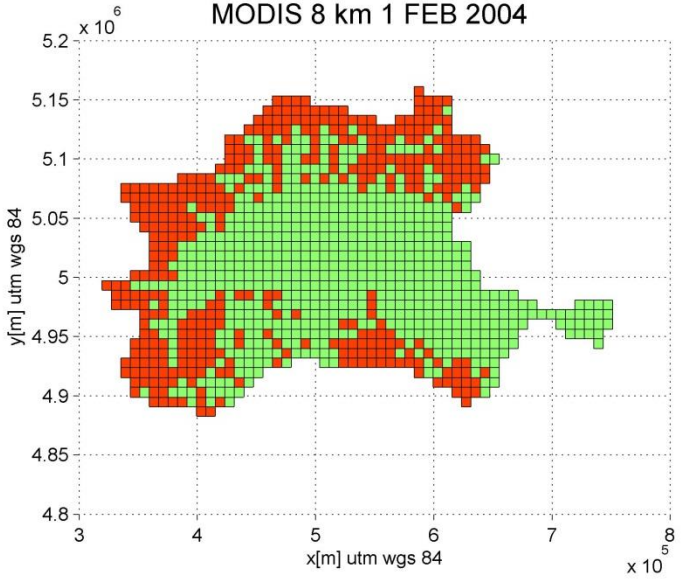


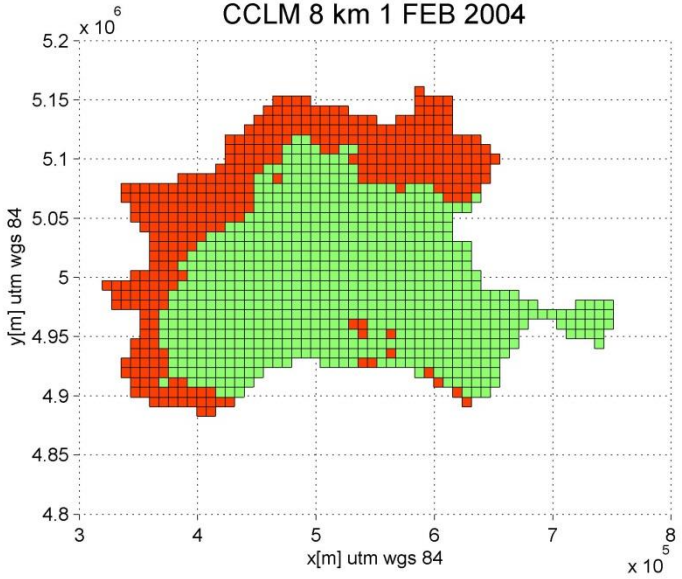


1) Use of snow cover maps to check the performance of Regional Climate Models

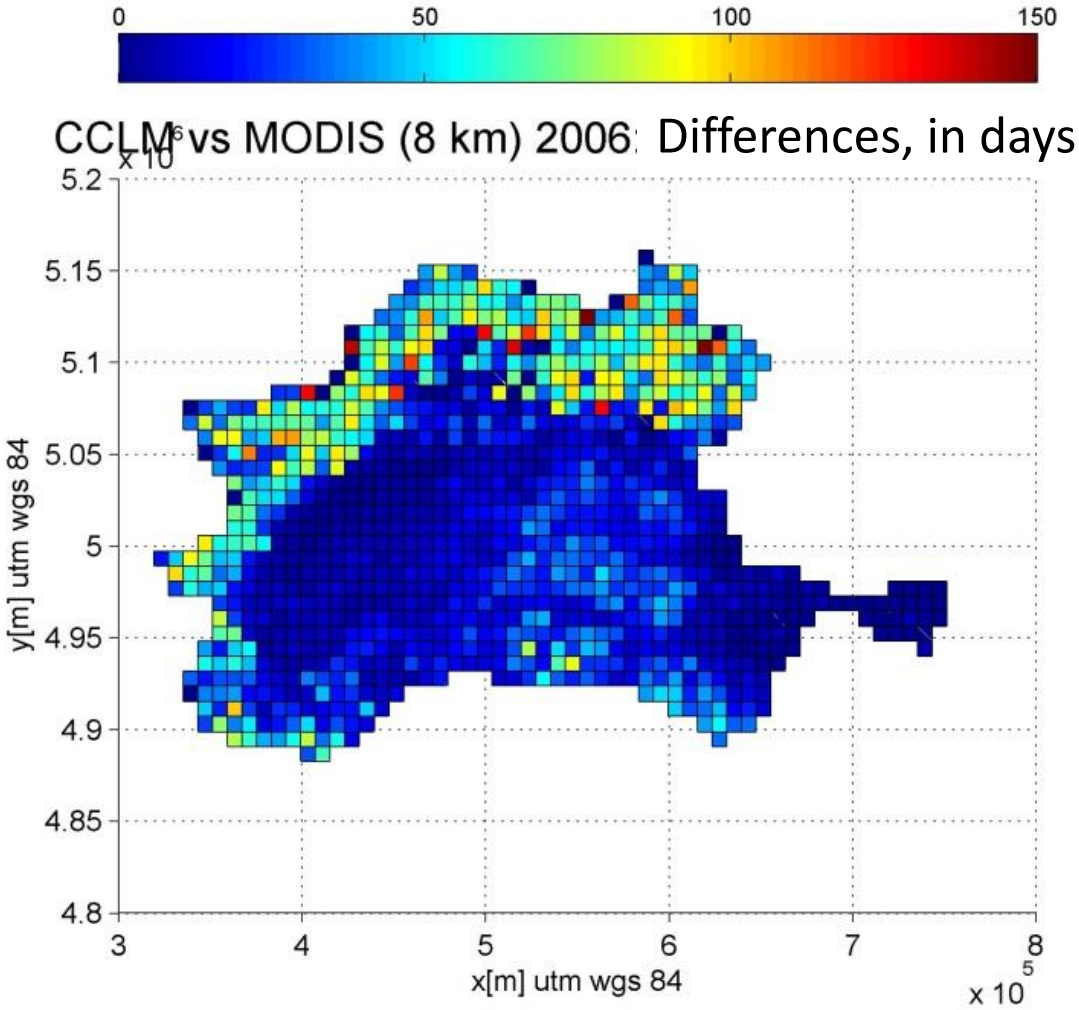






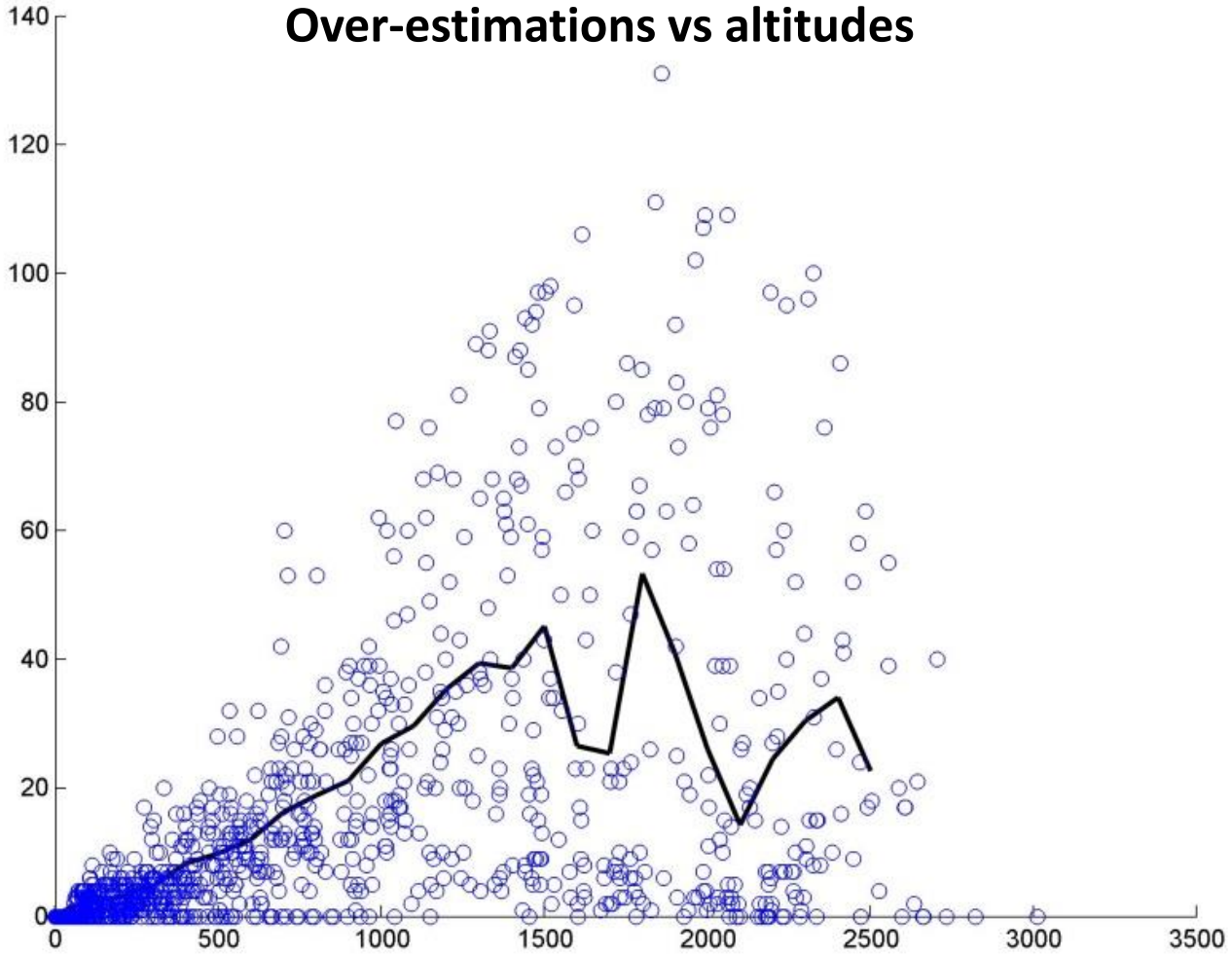


1) Use of snow cover maps to check the performance of Regional Climate Models

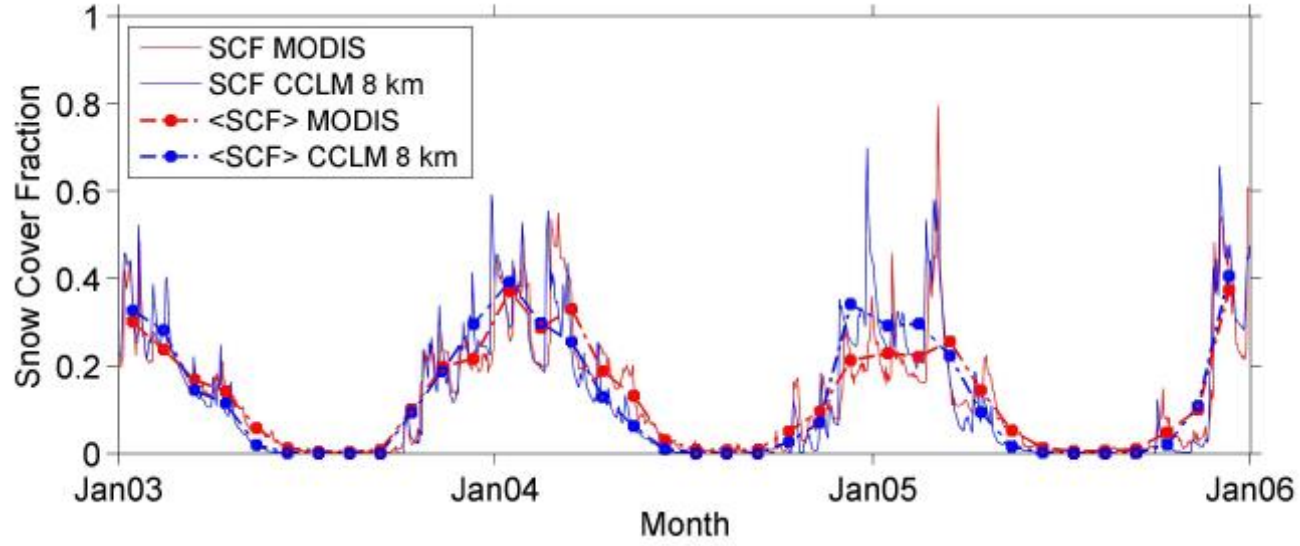


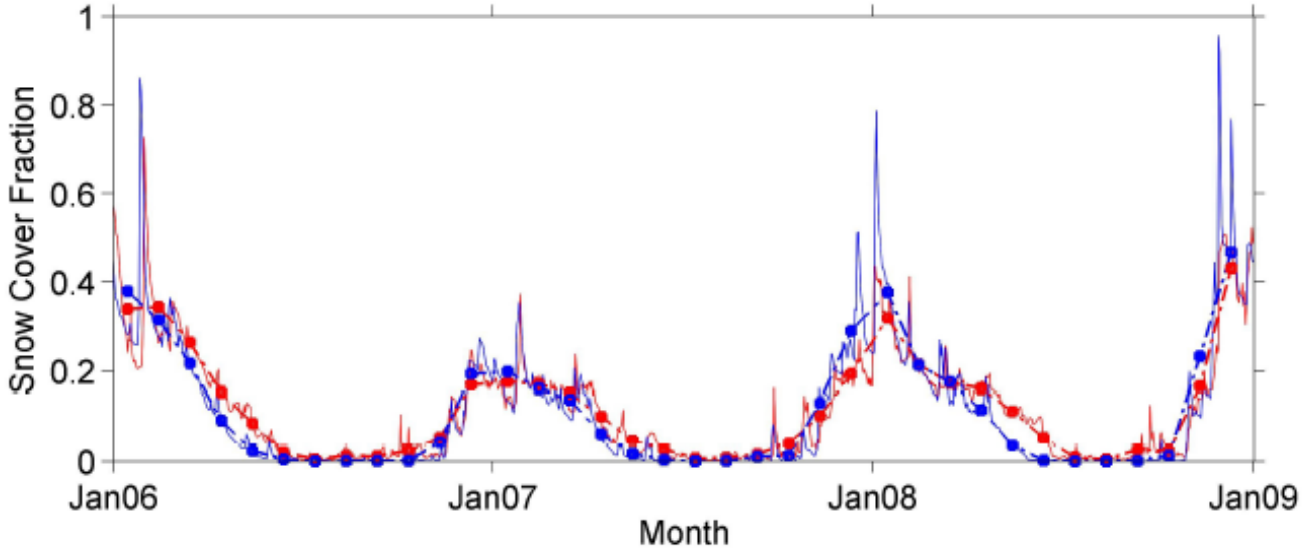
period **2003-2012**

1) Use of snow cover maps to check the performance of Regional Climate Models



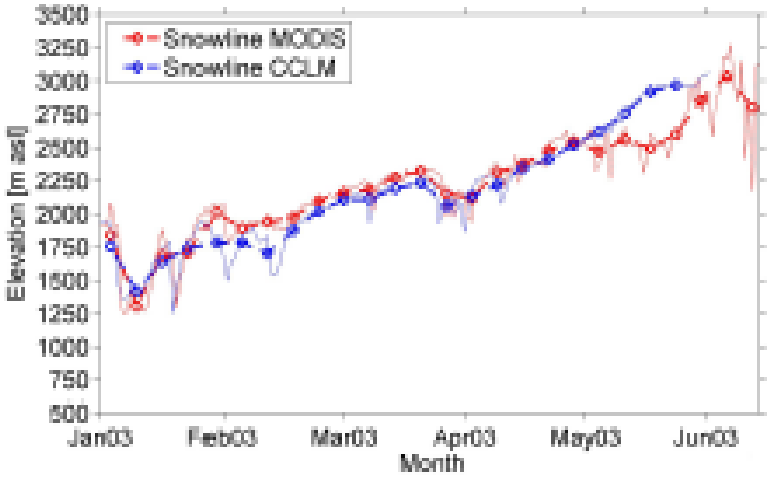
1) Use of snow cover maps to check the performance of Regional Climate Models



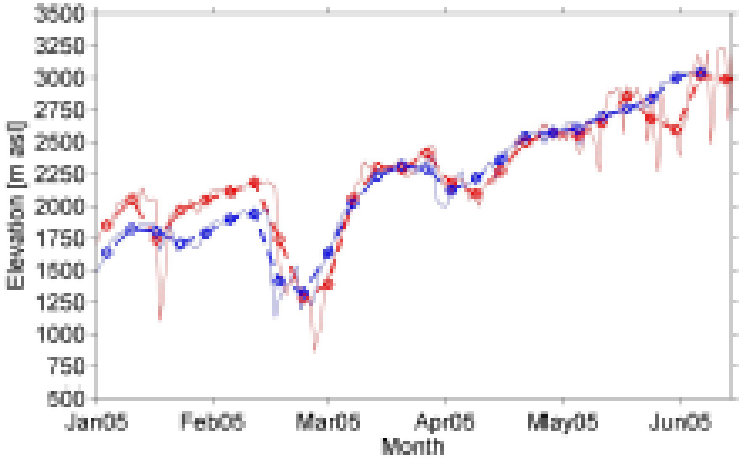


daily (−)
and average
monthly (−∘−)
values of
Snow Cover
Fraction

1) Use of snow cover maps to check the performance of Regional Climate Models

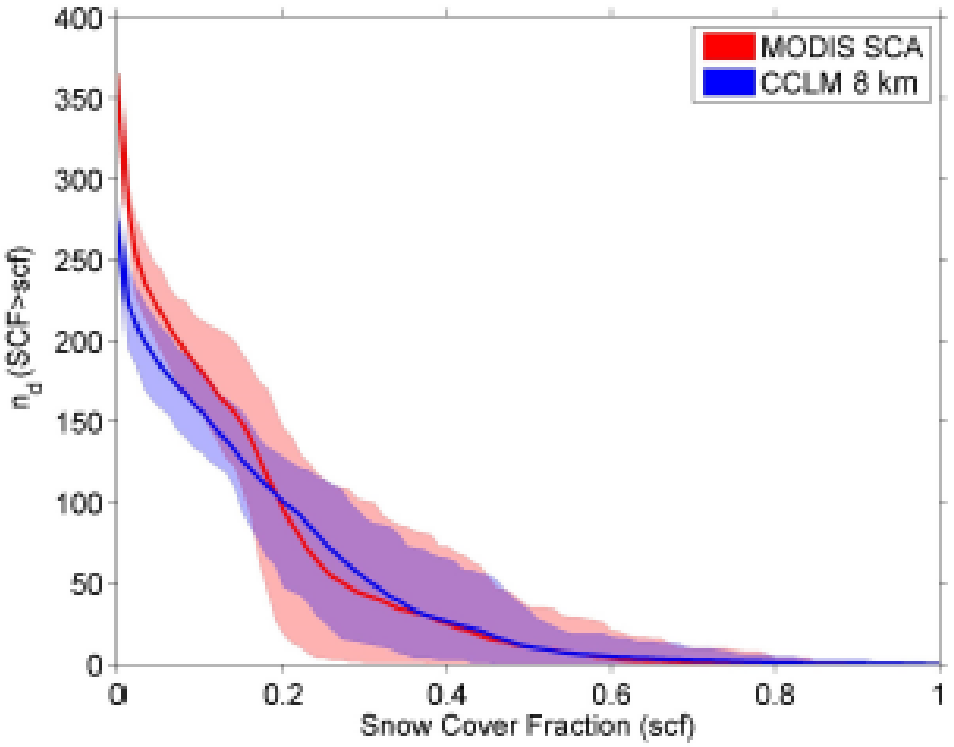


(a) 2003



(c) 2005

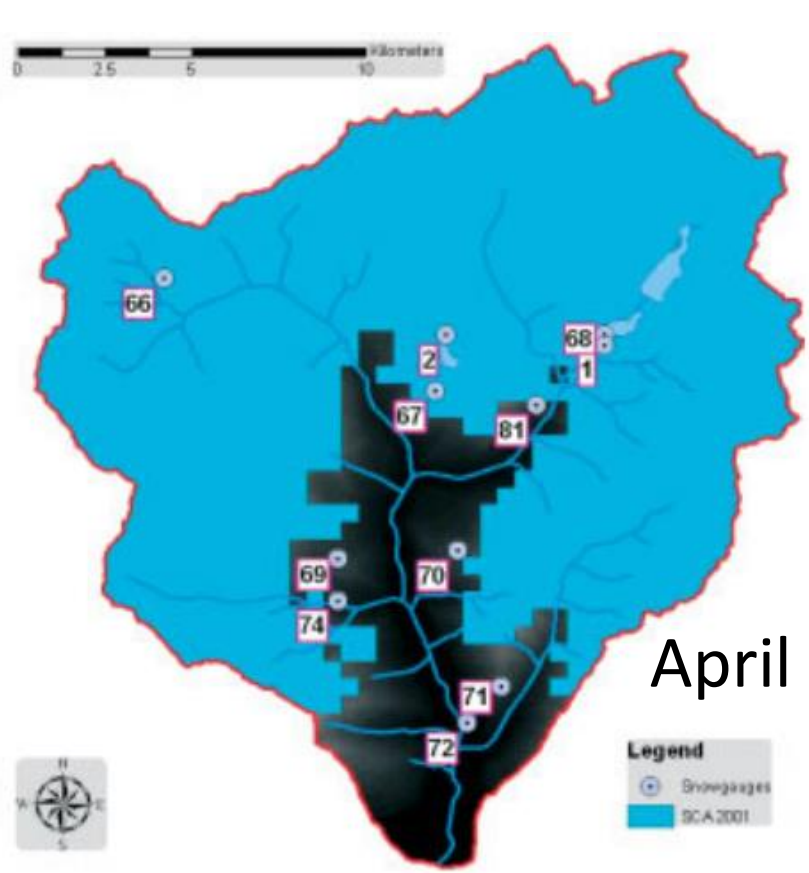
1) Use of snow cover maps to check the performance of Regional Climate Models

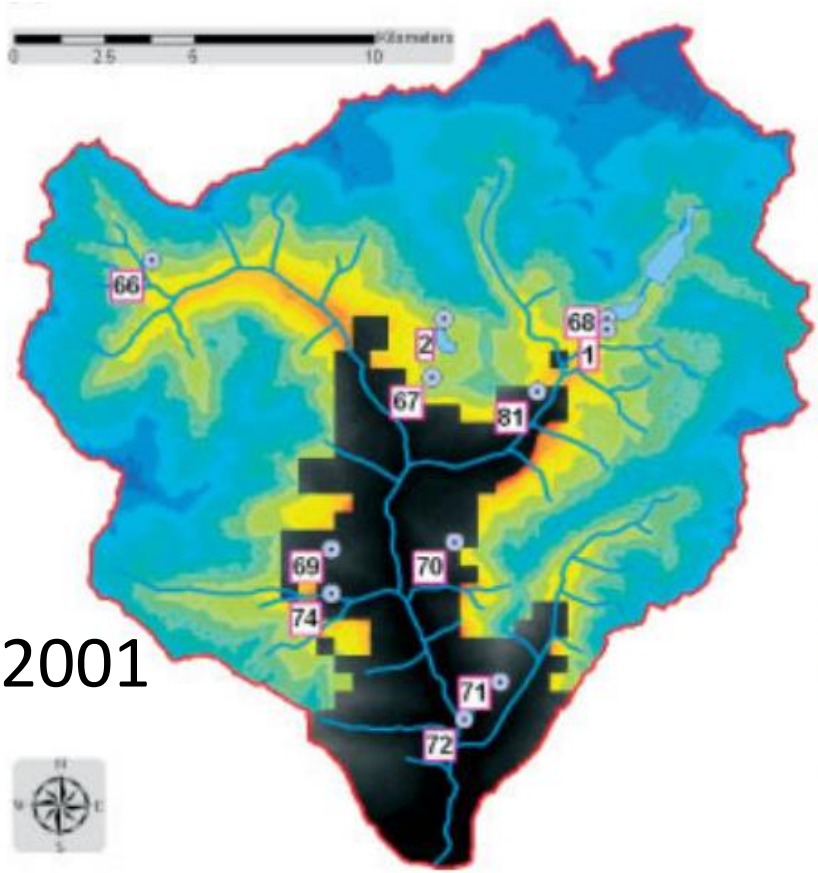


z > 0 m asl

Snow cover duration

2) Use of snow cover maps to provide inputs/constraint to Hydrological Models





April 1, 2001

used in a statistical model

Snow cover map → Snow Water Equivalent map

2) Use of snow cover maps to provide inputs/constraint to Hydrological Models

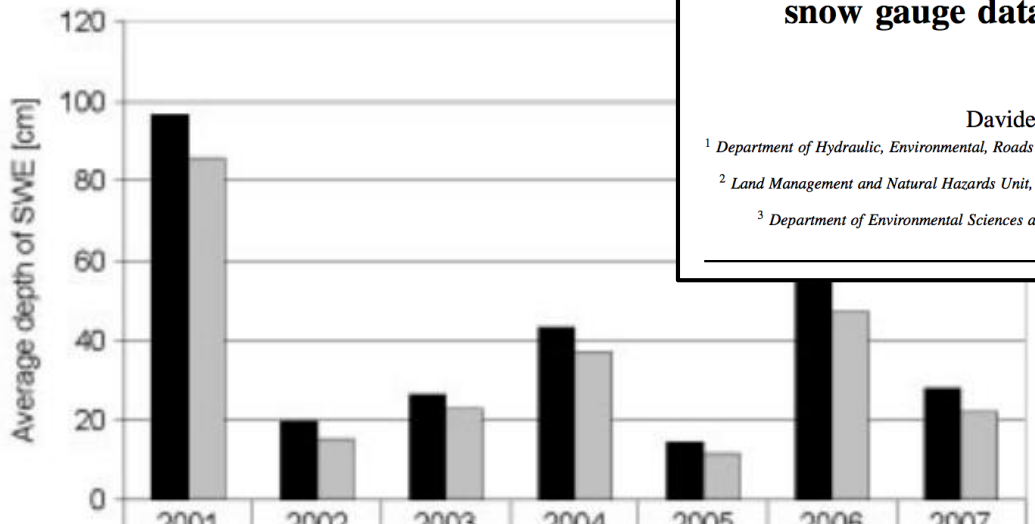
HYDROLOGICAL PROCESSES
Hydrol. Process. **23**, 1961–1972 (2009)
Published online 19 May 2009 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/hyp.7328

Snow water equivalent estimation in the Mallero basin using snow gauge data and MODIS images and fieldwork validation

Davide Bavera[1,2]* and Carlo De Michele[1,3]*

[1] *Department of Hydraulic, Environmental, Roads and Surveying Engineering, Politecnico di Milano, Piazza Leonardo da Vinci, 32 I-20133 Milano, Italy*
[2] *Land Management and Natural Hazards Unit, Institute for Environment and Sustainability, DG Joint Research Centre, European Commission, Ispra, Italy*
[3] *Department of Environmental Sciences and Engineering, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina*

(a)



	2001	2002	2003	2004	2005	2006	2007
with EO data	96.6	19.7	26.3	43.2	14.6	55.6	28.1
without EO data	85.9	15.5	22.9	37.2	11.6	47.0	21.9

Snow Water availability during the period 2001–2007 at the Mallero basin obtained using Equation (5) (gray bars) and conditioning the application of Equation (5) at SCA retrieved by MODIS (black bars).

2) Use of snow cover maps to provide inputs/constraint to Hydrological Models

Considering the following model:

J. Martinec, A. Rango, R. Roberts

Snowmelt Runoff Model (SRM) User's Manual

Edited by Enrique Gómez-Landesa & Max P. Bleiweiss

$$Q_{n+1} = [c_{Sn} \cdot a_n (T_n + \Delta T_n) S_n + c_{Rn} P_n] \frac{A \cdot 10000}{86400} (1-k_{n+1}) + Q_n k_{n+1}$$

The snowmelt-runoff model (SRM) is designed to simulate and forecast daily streamflow in mountain basins where snowmelt is a major runoff factor.
SRM was developed by Martinet in small European basins. With the advent of satellite snow-cover data in the 197O.s it became possible to test SRM in larger basins.

Daily discharge Q (m^3/s)
Daily air temperature T (° C),
SCA S (%) as percentage of A
Daily precipitation P (cm/day)

SRM has six parameters: Cs, Cr, a, ΔT, A, k.

2) Use of snow cover maps to provide inputs/constraint to Hydrological Models

According to SRM, the cumulated melted volume, V_M, over N days is estimated

$$V_M = \sum_{n=1}^{N} \alpha_n (T_n + \Delta T_n) S_n A$$

In the case of areas characterized by the seasonal snow cover only,
the accumulated snowpack at the end of the winter season, V_A, makes the initial condition, and thus the upper bound, for the total melted volume during the summer season, V_M.

2) Use of snow cover maps to provide inputs/constraint to Hydrological Models

Year	Parameter set	D_V (%)	R^2	V_M (Mm^3)
2003	MA	−0.041	0.796	117.61
	AC1	−0.829	0.856	268.46
	AC2	−4.698	0.774	*60.00*
	AC3	−1.244	0.881	116.92
	AC4	−3.315	0.857	*60.00*
2004	MA	0.728	0.688	122.17
	AC1	6.039	0.556	50.26
	AC2	6.039	0.556	*97.00*
	AC3	3.354	0.756	160.59
	AC4	2.640	0.753	*97.00*

HYDROLOGICAL PROCESSES
Hydrol. Process. (2011)
Published online in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/hyp.8376

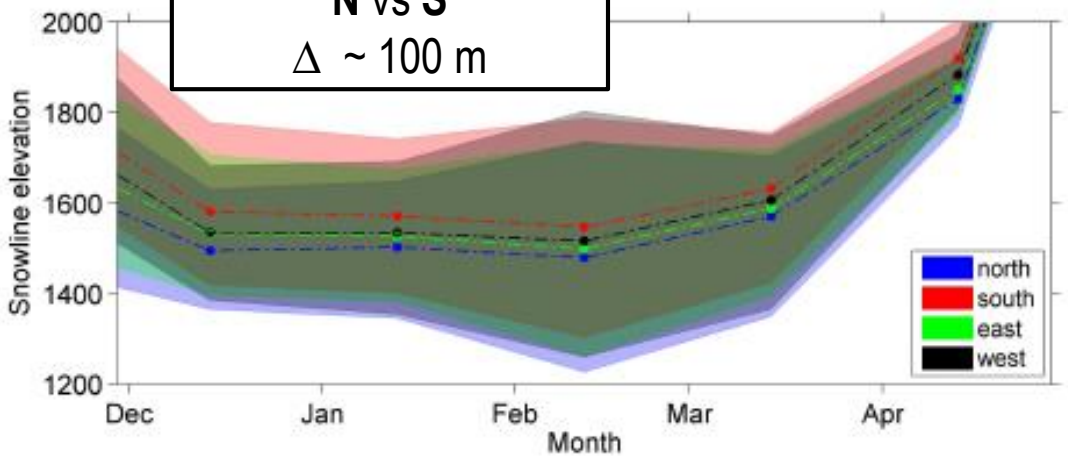
Melted snow volume control in the snowmelt runoff model using a snow water equivalent statistically based model

D. Bavera,[1,2] C. De Michele,[1]* M. Pepe[3] and A. Rampini[3]

[1] *DIIAR, Politecnico di Milano, P.zza L. da Vinci 32, Milano I20133, Italy*
[2] *Institute for Environment and Sustainability, DG JRC, European Commission Via E. Fermi 274921027 Ispra Va, Italy*
[3] *IREA, CNR, Via Bassini 15, Milano I20133, Italy*

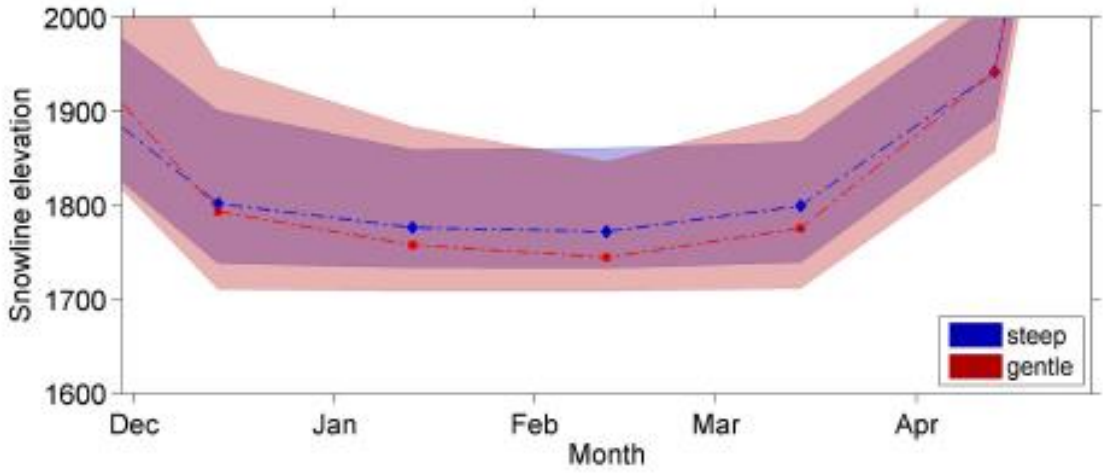
3) Use of snow cover maps to investigate impact of topographic controls

N vs **S**
Δ ~ 100 m



Snowline

Gentle vs **Steep**
Δ ~ 50 m

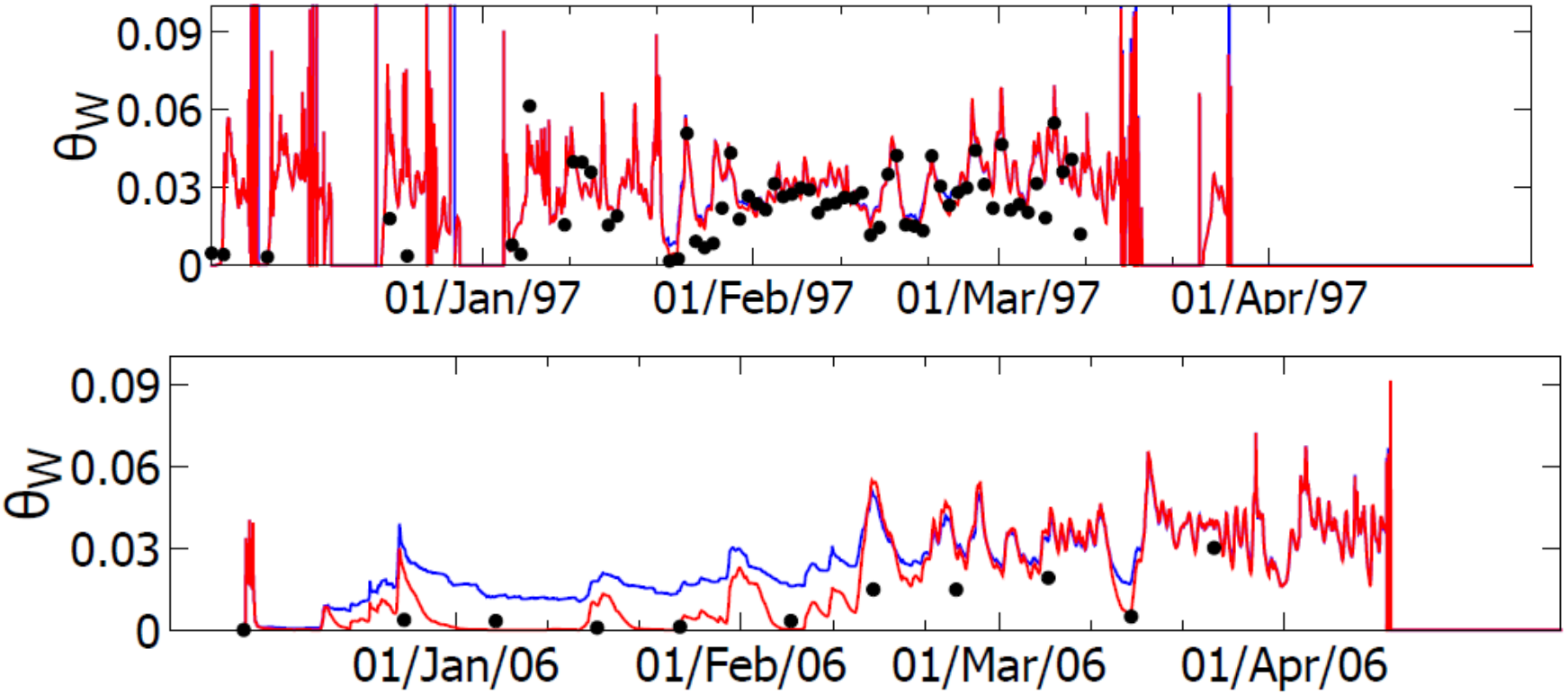


Future perspective

- **Use** of satellite products to investigate the snowpack wetness.
- **Use** of cloud cover maps to provide information about the energy balance.

Future perspective

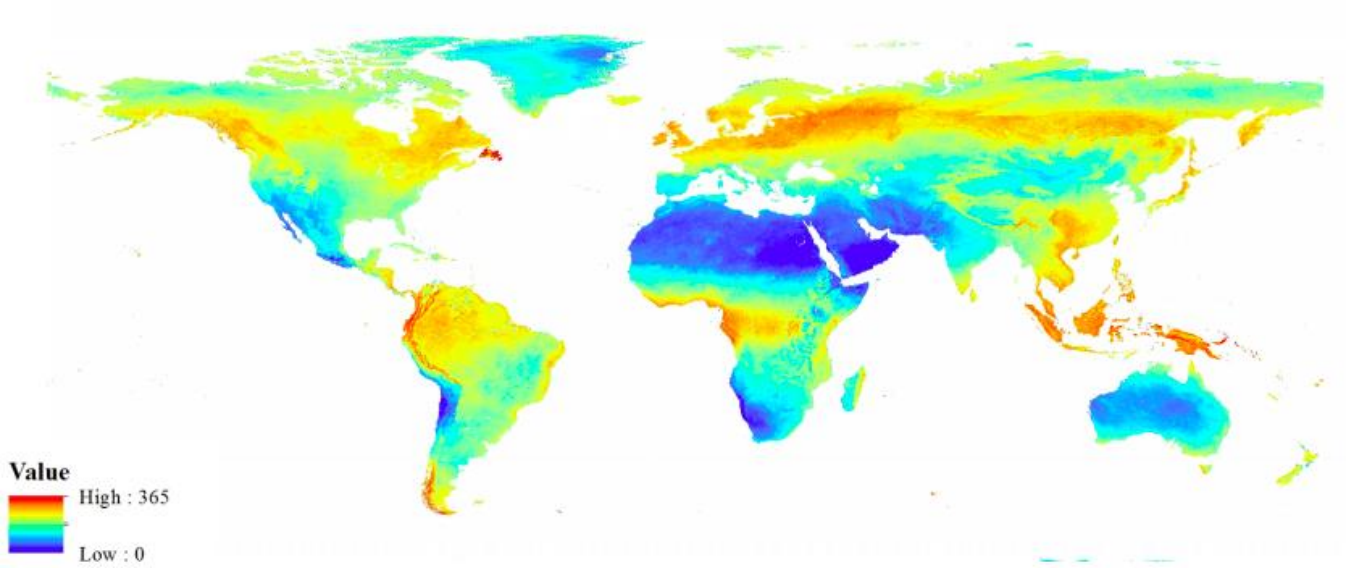
- **Use** of satellite products to investigate the snowpack wetness.



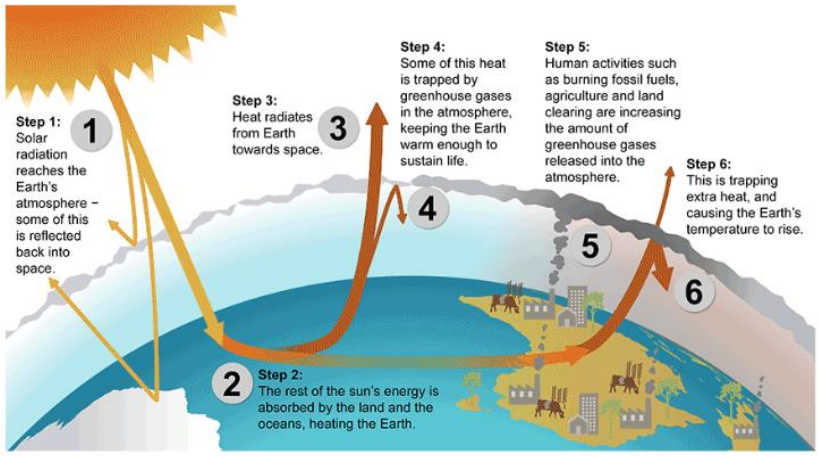
Black: data (manual), **Red**: HyS (with MF), **Blue**: HyS (without MF)

Avanzi, F., Yamaguchi, S., Hirashima, H., De Michele C. 2015. Bulk volumetric liquid water content in a seasonal snowpack: modeling its dynamics in different climatic conditions. *Advances in Water Resources*.

Future perspective
- Use of cloud cover maps to provide information about the energy balance



2017 cloud cover from Aqua



References

- Bavera D., De Michele C., Snow water equivalent estimation in the Mallero basin using snow gauge data and MODIS images and fieldwork validation, Hydrological Processes, 2009.

- Bavera D., C. De Michele, M. Pepe, A. Rampini, Melted snow volume control in the snowmelt runoff model using a snow water equivalent statistically based model, Hydrological Processes 26 (22), 3405-3415, 2012.

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- Da Ronco P., De Michele, C.: RP0182 – On the use of MODIS Snow Cover Product for assessing snow extension and duration over the Po river basin. CMCC research papers, http://www.cmcc.it/it/publications/rp0182-on-the-use-of-modis-snow-cover-product-for-assessing-snow-extension-and-duration-over-the-po-river-basin, 2013.

- Da Ronco P. and **De Michele, C**.: Cloud obstruction and snow cover in Alpine areas from MODIS products, Hydrol. Earth Syst. Sci., 18, 4579-4600, doi:10.5194/hess-18-4579-2014, 2014.

- Da Ronco P., De Michele, C., Montesarchio, M., & Mercogliano, P. (2016). Comparing COSMO-CLM simulations and MODIS data of snow cover extent and distribution over Italian Alps. Climate Dynamics, 1-23, 2016.

- Da Ronco P., F. Avanzi, C. De Michele, B. Schaefli. Topographic signature on snow dynamics in Central Apennines from Terra and Aqua satellites. To be submitted to “Remote Sensing of Environment”, in preparation.