About the use of snow satellite products in hydrological modelling

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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 ~ $74 \cdot 10^3$ 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

Legend

MODIS Terra: 1 Jan 2005
- Green: Land
- Light blue: Cloud
- Red: Snow

1 Jan 2005
Cloud cover frequency in the Po river basin

Number of cloudy days - year 2008
Cloud obstruction over Po river basin

<table>
<thead>
<tr>
<th>Year</th>
<th>JFM</th>
<th>AMJ</th>
<th>JAS</th>
<th>OND</th>
</tr>
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<tbody>
<tr>
<td>2003</td>
<td>0.47</td>
<td>0.64</td>
<td>0.41</td>
<td>0.59</td>
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<tr>
<td>2004</td>
<td>0.60</td>
<td>0.68</td>
<td>0.52</td>
<td>0.61</td>
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<tr>
<td>2005</td>
<td>0.50</td>
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<td>2006</td>
<td>0.54</td>
<td>0.68</td>
<td>0.52</td>
<td>0.45</td>
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<td>0.61</td>
<td>0.66</td>
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<td>0.51</td>
<td>0.77</td>
<td>0.50</td>
<td>0.60</td>
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<tr>
<td>2009</td>
<td>0.54</td>
<td>0.67</td>
<td>0.46</td>
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<td>0.72</td>
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<td>0.62</td>
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<tr>
<td>2011</td>
<td>0.54</td>
<td>0.64</td>
<td>0.45</td>
<td>0.46</td>
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<tr>
<td>2012</td>
<td>0.50</td>
<td>0.71</td>
<td>0.48</td>
<td>0.59</td>
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</table>

In spring higher is the percentage of cloudiness!
A cloud removal procedure

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

Cloud obstruction and snow cover in Alpine areas from MODIS products

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\textsuperscript{2}Politecnico di Milano, Department of Civil and Environmental Engineering, Milano, Italy
1) Use of snow cover maps to check the performance of Regional Climate Models

- 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

![Graph](image1.png)

(a) 2003

![Graph](image2.png)

(c) 2005
1) Use of snow cover maps to check the performance of Regional Climate Models

Snow cover duration

\( z > 0 \) m asl
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**

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

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

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

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 1970s it became possible to test SRM in larger basins.

SRM has six parameters: \( C_s, C_r, a, \Delta T, A, k \).
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**

<table>
<thead>
<tr>
<th>Year</th>
<th>Parameter set</th>
<th>$D_V$ (%)</th>
<th>$R^2$</th>
<th>$V_M$ (Mm$^3$)</th>
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<td>97.00</td>
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</table>

HYDROLOGICAL PROCESSES


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

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

- N vs S
  - $\Delta \sim 100$ m

- Snowline

- Gentle vs Steep
  - $\Delta \sim 50$ 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)

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

2017 cloud cover from Aqua


