Impact of snow drift on snow cover in the central Apennines simulated with the WRF/Noah-MP model

Edoardo Raparelli$^{1,2}$, Paolo Tuccella$^{1,2,5}$, Valentina Colaiuda$^4$, Francesco L. Rossi$^4$, Raffaele Lidori$^2$

$^1$Dipartimento di Scienze Fisiche e Chimiche, Università degli Studi dell’Aquila, Italy

$^2$Center of Excellence Telesensing of Environment and Model Prediction of Severe events (CETEMPS), Università degli Studi dell’Aquila, Italy

$^4$Agenzia di Protezione Civile - Regione Abruzzo, L’Aquila, Italy

$^5$Comitato Glaciologico Italiano, Torino, Italy.
Snow Drift

- It causes inhomogeneous snow height
- Snow eroded from wind exposed surfaces and deposited on wind sheltered surfaces
- Wind-induced snow transport occurs when the wind speed exceeds a threshold value, which depends on the snow type at the surface
- Three modes of snow transport: reptation, saltation and turbulent suspension
  - Reptation: the rolling of particles over the surface of the snowpack (negligible)
  - Saltation:
    - particles follow ballistic trajectories close to the ground
    - returning to the surface they may rebound and/or eject new grains
  - Turbulent suspension:
    - occurs above the saltation layer
    - snow grains are transported by turbulent eddies.
- Distances of transport limited by the sedimentation and sublimation of snow grains
- Sublimation modifies the vertical profiles of temperature and humidity near the surface

Taken from Yoshihide Tominaga, 2018
WRF-NOAH-MP model configuration and evaluation

- Central Italy is a region characterized by complex terrain, it is crossed by Apennines mountain chain and is surrounded by the Adriatic and Tyrrhenian seas. These features result in a high micro-climate variability.
- WRF has been configured with four nested domains. The innermost domain has a resolution of 1 km and is centered on the Abruzzo region, where the Apennine chain reaches its highest elevation (2912).
- NOAH-MP is used in the online configuration embedded in WRF.
- Snow height predicted by WRF-NOAH-MP is evaluated with data from manual stations maintained by the MeteoMont service.
- Model evaluation has been performed dividing the Abruzzo in 5 «meteo-nivological alert area», which are geographical areas that are homogeneous in terms of climate and snow conditions and are characterized by a uniform response during the occurrence of avalanche phenomena.
Model Evaluation

- **Gran Sasso Est - Laga Est**
  - Obs
  - CTRL
  - $r = 0.77$
  - MB = 11 cm
  - RMSE = 16 cm
  - STDE = 13 cm

- **Gran Sasso Ovest**
  - Obs
  - CTRL

- **Velino-Sirente**
  - Obs
  - CTRL

- **Majella**
  - Obs
  - CTRL

- **Parco Nazionale d'Abruzzo**
  - Obs
  - CTRL
Snow Drift Parameterization

Flux in the saltation layer:

\[ F_{salt} = e(u_*^2 - u_{*,th}^2) \]

\[ F_{salt} = 0.0014 \rho_a u_*(u_* - u_{*,th})(u_* + 7.6u_{*,th} + 205) \]

\[ u_{*,th} = 0.0195 + \sqrt{0.021 \rho_s} \]

Suspension snow flux:

\[ F_{bc} = C_D u_{10} (c_{salt} - c_{surf}) \]

Blowing snow is transported as a tracer using the transport scheme of WRF.

Blowing snow sublimates according to the simulated atmospheric conditions and deposits with an assumed settling velocity.
Results

<table>
<thead>
<tr>
<th>Location</th>
<th>Obs</th>
<th>CTRL</th>
<th>TEST-1</th>
<th>TEST-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gran Sasso Est - Laga Est</td>
<td>0.77</td>
<td>11</td>
<td>16</td>
<td>13</td>
</tr>
<tr>
<td>Gran Sasso Ovest</td>
<td>0.73</td>
<td>9</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>Velino-Sirente</td>
<td>0.73</td>
<td>10</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>Majella</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parco Nazionale d’Abruzzo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>r</th>
<th>MB</th>
<th>RMSE</th>
<th>STDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTRL</td>
<td>0.77</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>TEST-1</td>
<td>0.73</td>
<td>9</td>
<td>13</td>
</tr>
<tr>
<td>TEST-2</td>
<td>0.73</td>
<td>10</td>
<td>13</td>
</tr>
</tbody>
</table>
Results

CAMPO IMPERATORE - Gran Sasso Ovest

PRATI DI TIVO - Gran Sasso Est - Laga Est

COPPO DELL’ORSO - Parco Nazionale d’Abruzzo

LA CROCETTA - Velino-Sirente