Snow cover dynamics and snow hydrology of the Lebanese Mountain Chains

Using an integrated remote sensing and hydrologic modeling approach

Impact of snow melt on the hydrologic and water resources systems, Lebanon

Abbas Fayad
Centre d'Etudes Spatiales de la Biosphère (CESBIO/IRD, UPS), Toulouse, France
Content

• Current state of the water resources in Lebanon
• Hydrological water budget – Mount Lebanon & Anti Lebanon
• Importance of snow cover in Lebanon
• Interaction between climate, hydrology, snow, and water systems
• Knowledge on climate and its implications on hydrology, snow, and water resources
• Research objectives and methodology
Figure 1. Eastern region of the Mediterranean Sea
Current state of the water resources in Lebanon

• Water scarcity is believed to be one of the main problems currently facing the country
  – Limited water sources
  – Increased water demands by all sectors
  – Inefficiencies in water supply systems and in water use

• Increasing pollution of water resources (contributing to water scarcity)
  – Associated to human and agricultural activities and industrial processes

• More work is needed to link the hydrologic processes to water resources management.
Figure 2. (a) Major Lebanese river basins and transboundary basins; (b) and major karstic and hydrogeological units
# Hydrological water budget – Mount & Anti Lebanon

<table>
<thead>
<tr>
<th></th>
<th>Lebanon</th>
<th>Mount Lebanon</th>
<th>Anti Lebanon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (km²)</td>
<td>10400</td>
<td>3400</td>
<td>2800</td>
</tr>
<tr>
<td>Karstification</td>
<td>65%</td>
<td>~75%</td>
<td>~85%</td>
</tr>
<tr>
<td>Precipitation (mm/year)</td>
<td>800-950 (avg. 840)</td>
<td>1000-1600 (avg. 1220)</td>
<td>550-850 (avg. 620)</td>
</tr>
<tr>
<td>Snow contribution</td>
<td>20-32.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>40- 55%</td>
<td>40- 50%</td>
<td>45- 60%</td>
</tr>
<tr>
<td>Surfacewater</td>
<td>25-27.5%</td>
<td>5-15%</td>
<td>&lt;5%</td>
</tr>
<tr>
<td>Groundwater</td>
<td>5-12.5%</td>
<td>27.5%</td>
<td>32.5%</td>
</tr>
<tr>
<td>Recharge</td>
<td></td>
<td>42.5%</td>
<td>45%</td>
</tr>
<tr>
<td>Percolation to groundwater and flow into the sea †</td>
<td>5-9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface water loss- neighboring countries‡</td>
<td>6-7.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underground water loss -neighboring countries</td>
<td>2-3.5%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† Includes groundwater seepage in Lebanon and groundwater losses to the sea and neighboring countries. ‡ Excludes water flow to the sea. * Average (2002-2011)

Importance of snow cover in Lebanon

• Snow contributes to the definition of the hydrologic system of most River Basins in Lebanon.
  – Despite its importance, little is known about the snowpack dynamics.

• In fact, it is estimated that between 30 to 40% of the annual precipitation over Lebanon falls as snow (Shaban et al., 2004; Aouad-Rizk et al., 2005).

• A recent study demonstrated that snow cover contributes to the hydrological budget ranges between 1700 and 2800 MCM/Year (average 2400 MCM/Year) (Mhawej et al., 2014)
Interaction between snow cover and spring discharge

Figure 4: Snow cover probability from MODIS product (= % of snow days per year)
Interaction between snow cover and spring discharge

Figure 3. (a) Spring discharge over average dry and wet years; (b) snow cover area over same time period
Interaction between climate, hydrology, water use – The Litani

Figure 3. Average Discharge at Quaraoun Gauge (1960-2010), Litani River Basin (~ 1550 square km)
Knowledge on climate and its implications on hydrology, snow, and water resources - Lebanon

- **Temperature (Increase):** +1 °C coastal & +2 °C inland by 2040
- **Precipitation (Decrease):** Between 10% & 20% by 2040
- **Evapotranspiration (Increase):** Coastal: 1% by 2044; Mountain: 5% by 2044; Inland: 26% by 2044
- **Hydrology and Hydrogeology (Decrease):** Decreasing surface runoff and groundwater recharge (variable depending on basin)
- **Snow:**
  - Snowfall (Decrease): reduced season between 2 and 6 weeks
  - Snow depth (Decrease): 50% w/ 2°C warming (mean ~-20cm @ Cenomanian plateau of Nahr Ibrahim (2,000m altitude))
  - Snow fall (Retreat): to 1500 - 1700m w/2 °C warming
  - Snowpack volume (decrease): 1200 – 700 MCM w/ +2°C
- **Water Resources (Decrease):** -12 to 16 % at 2 °C warming

Lebanon’s vulnerability to climate variability?

Change in hydrologic regimes?
Impact snow?
Water scarcity?
Research objectives and methodology

Objective 1: Monitor Snow Cover Area
- Remote Sensing Data
- Snow Cover Area (SCA)
- Derivation of Snow Cover Area (SCA)
- Accuracy check

Objective 2: Model Snowpack Dynamics
- In situ measurements & Meteo. variables
- Snowpack Modeling
- Snow Water Equivalent (SWE)
- Modeling Snow Melt (SEB/DDM)
- Cross-Validation

Objective 3: Model Snow Hydrology
- Meteo. variables
- Basin Characteristics
- Surface flow, Spring Discharge
- Snow-Hydrologic Model Formulation
- Model Calibration/Validation
- Analysis and results
- Model Selection: Distributed/ Semi-Distributed

Figure 4. Workflow for the Integrated Snow-Hydrology Modeling Framework
Specific objectives and key outcomes

- **Objective 1: Monitor Snow Cover Area**
  - Mapping SCA using existing remote sensing products and techniques
  - Linking SCA and physio-climatic factors
- **Objective 2: Model Snowpack Dynamics**
  - Estimate SWE on Mount-Lebanon
  - Model snow melt from snowpack
- **Objective 3: Model Snow hydrology**
  - Interaction between snow depletion and hydrologic regimes
  - Modeling snow dynamics impacts on the hydrologic system