Assessing Climate impacts on the Quantity and quality of WAter

Deliverable D.Data.3b: Remote-sensing data online- month 36

Dissemination level: Public

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1. Introduction

1.1 Contributors to the deliverable

LTHE-CNRS (Partner 13):
The LTHE laboratory ("*Laboratoire d'étude des Transferts en Hydrologie et Environnement*") is a joint-lab of CNRS (UMR 5564) partnered with University of Grenoble, France (*http://www.lthe.fr/LTHE/*). Created in 1992 and actually managed by Director Thierry Lebel, this research unity is an interdisciplinary laboratory focused on hydrology, climate and environment. Several scientific fields are developed for these issues by a permanent staff of 65 researchers and professors: water cycle and management, flooding, hydrology and climate modelling, sensors development, mountain hydrology (snow and ice).

Jean-Pierre Dedieu:
Dr. Jean-Pierre Dedieu is a permanent research scientist (senior) of CNRS since 1986. Specialized in Remote Sensing of the cryosphere since 20 years (optical to SAR), his experience is largely dedicated to snow and ice monitoring in high mountains regions (climate and hydrology). Many publications were focused on the use of optical data (visible to infra-red) for snow characteristics retrieval: (i) Snow Covered Area (SCA) percentage mapping at the sub-pixel size, important issue for meteorological application and hydrological modelling of runoff; (ii) Snow Grain Size (SGS) at the snow surface mapping, important effect on the snow albedo and important parameter for any study which needs energy balance at the surface. A strong experience is also acquired in active radars (SAR) for dry and wet snow mapping inferred from dual- and quad-polarization sensors (Envisat, SIR-C) under high elevation conditions. The objective is to retrieve the snow pack water equivalent (SWE) using field measurements network points to calibrate the model. Then, publications were published concerning the use of optical remote sensing data for time-series of glacial mass balance reconstruction in the French Alps jointly with LGGE-CNRS, also partner 13 of the ACQWA project.

1.2 Scope and Purpose of the Task 2.3: Remote-sensing data

Task 2.3 is implemented into the Workpackage 2 of the ACQWA project: *Climate and Socio-Economic Drivers of Change*. WP 2 provides a quantitative description of the primary (or direct) driver, climate change (CC), and of the indirect (or secondary) driver, the socio-economic factors. Task 2.3 is specifically dedicated to validation of spatial and temporal extent of snow cover at global to local scale computed by spatially explicit models under different hydrological and climate scenarios. Four watersheds are dedicated to the WP2.3 task: two in Europe (Rhone, Po), one in Chile and one in the Kyrgyz Republic (Kyrgyzstan).

Because the proposal concentrates on modelling the response of snow and ice dominated mountain regions, a specific Task is foreseen to generate remote sensing optical products, which will be used for validation of both climatic and hydrological models, used in Task 3.1 and 3.2 of WP3, with respect to the spatiotemporal evolution of snow cover and the surface characteristics (e.g. the snow grain size) of the snow pack in the present climate at the regional, basin and local scales. Such validation is necessary to verify that both the climate and the hydrological models can capture the variability observed, and, particularly, that which has characterized extreme years with rapidly evolving snow cover.

Accordingly, enhanced snow cover products are produced from daily large scale image, i.e. 500m to 250m MODIS/TERRA database, and validated to local scale representative case using monthly ASTER versus SPOT HRVIR data (respectively 15m and 10m). Specific MODIS products are used such as the surface reflectance (MOD09, Bands 1-7, 500 m), the cloud mask (MOD35), the geometry (MODMGGAD), jointly with the relevant Digital Elevation Models (DEMs) of the investigated areas.

2. Snow cover retrieval over Chile and Kyrgyzstan river basins from MODIS optical satellite data

2.1 Context and Objectives:

Estimation of the Snow Covered Area (SCA) is an important issue for meteorological application and hydrological modeling of runoff. With spectral bands in the visible, near and middle infrared, the MODIS optical satellite sensor can be used to detect snow cover because of large differences between reflectance from snow covered and snow free surfaces. At the same time, it allows separation between snow and clouds. Moreover, the sensor provides a daily coverage of large areas (2,500 km range).
However, as the pixel size is 500m x 500m, a MODIS pixel may be partially covered by snow, particularly in Alpine areas, where snow may not be present in valleys lying at lower altitudes. Also, variation of reflectance due to differential sunlit effects as a function of slope and aspect may be present in images. Nevertheless, it is possible to estimate the FRaction of snow Area (FRA) at the sub-pixel level (percentage) with a relatively good accuracy. Satisfactory results are provided if the sub-pixel estimations are integrated for a few pixels relative homogeneity to an entire watershed.

2.2 Data:

The complete satellite images database was extracted from the U.S. MODIS/NASA website (*http://modis.gsfc.nasa.gov/)* for MOD09_B1 Reflectance images, and from the MODIS/NSIDC website (*http://nsidc.org/index.html*) for MOD10_A2 snow cover maps. Only the Terra platform was used because images are acquired in the morning and are therefore better correlated with dry snow surface, avoiding cloud coverage of the afternoon (Aqua Platform). Daily and 8-day data were extracted for the last decade (2000-2010).

2.3 Methodology:

The MOD10_A2 product and the MOD9_B1 Image reflectance products were respectively analyzed to retrieve maximum snow cover (SCA) and Fractional Snow cover at sub-pixel scale (FRA). All products were retrieved at 8-days over a complete time period of 10 years (2000-2009), giving 500 images for each river basin.
Digital Model Elevation (DEM) was given by NASA/SRTM database at 90-m resolution and used (i) for illumination versus topography correction on snow cover, (ii) geometric rectification of images. Geographic projection is WGS84, UTM. Maximum Snow Cover mapping (SCA) was retrieved from the NSIDC database classification (Hall et al., 2001). Fractional Snow cover mapping (FRA) was derived from the NDSI linear regression method (Salomonson et al., 2004).

Cloud mask was given by MODIS-NASA library (radiometric threshold) and completed by inverse slope regression using DEM (Derrien, 1990) to avoid lowlands fog confusing with thin snow cover.

2.4 Results:

Deliverable D.Data.3.1 (Month 12, 2009) exposed the first part of WP2.3 task during Year-1 of the ACQWA Project. This Deliverable report describes the complete work applied over 2 Alpine watersheds in Europe. The first area is Rhone river basin upper Geneva Lake: Canton du Valais, Switzerland (5'375 km²). The second one is the Upper Po watershed, including Val d'Aosta and Piemonte regions (37'190 km²). Watersheds boundaries were provided under vector file respectively by GRID (CH) and ARPA (IT) partners and validated by ACQWA coordinator.
Due to lack of consistent data information with local partners concerning the two last watersheds (Chile and Kyrgyzstan), a shift in DoW was requested at Year-1 to postpone at month 24 the application on Chile and at month 30 the one for Kyrgyzstan. Deliverable D. Data.3.2 can now be produced on time at month 36.
The two last watersheds of the ACQWA project are located in dry regions where snow and ice melting from the mountain ranges are necessary for hydropower and supply for domestic use of water (drinking, agriculture). The Chilean watershed concerns the upper part of the Aconcagua river (5'806 km²) in the dry part of the Andes. The watershed located in the Kyrgyz Republic involves all upper streams of the Syr Darya formation zone (111'895 km²). Data and methodology applied are the same are described in Deliverable Data.3.1 (DEM, Modis images, SCA and FRA outputs) for the 2000-2010 time period.
Figure 1 (Chile) and Figure 2 (Kyrgyzstan) expose two examples of output statistical maps retrieved from the 10-year MODIS database.

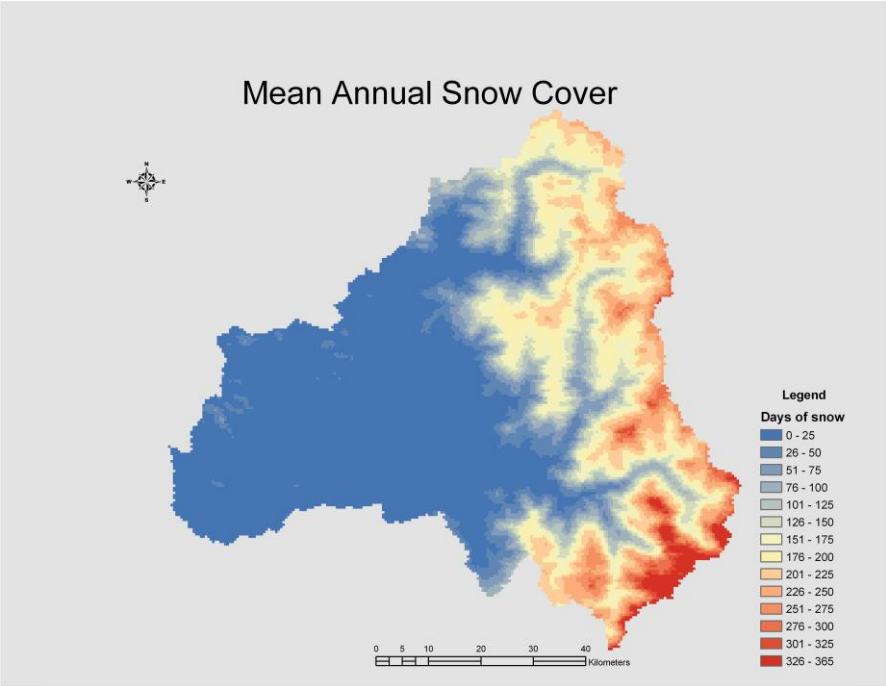

Figure 1: Mean number of snow days/year over 2000-2010 time period for upper Aconcagua river(Chile).

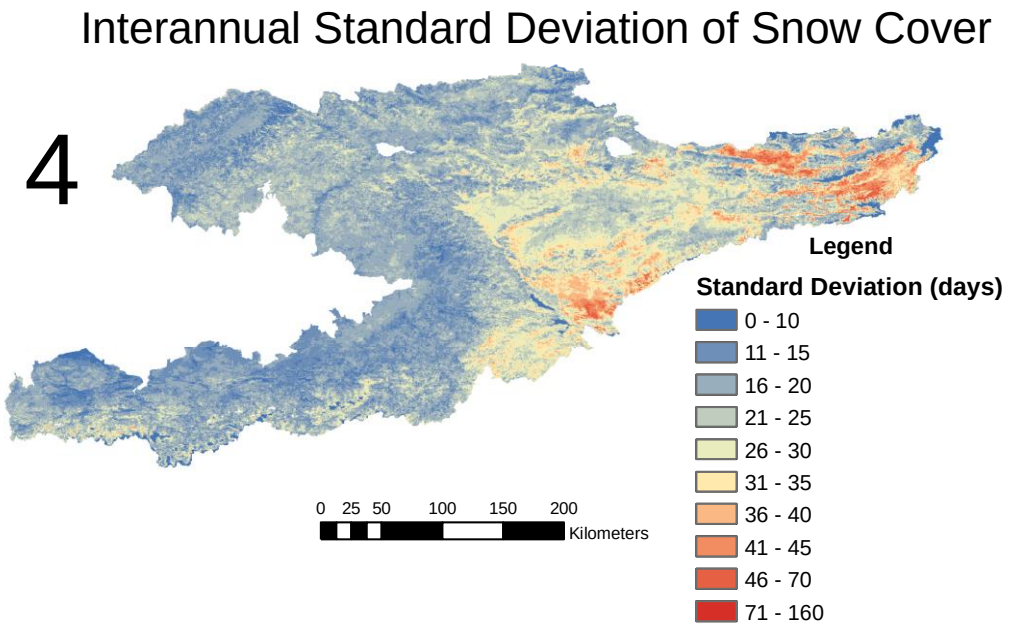

Figure2: Standard deviation in days of snow cover over 2000-2010 time period For the Syr Darya formation zone Kyrgyzstan)

2.5 ACQWA Data Warehouse implementation:

Maps of snow cover for the four watersheds are on-line and available on the ACQWA Data Warehouse site. We have also implemented guidelines and other data used or created for the WP 2.3 task (DEMs, Land Use, Shape files of the watersheds).

The link and architecture are the following:
https://netstorage.unige.ch/netstorage/

Into the "New Acqwa data warehouse" directory, four watersheds are listed:
04 RHONE
05 PO
06 CHILE
07 KYRGYZSTAN

For each watershed, we have provided the following products:

- Folder "LANDUSE":

* Polygons and Polylines shape files of the watershed area (WGS84, UTM)
* Globcover 2009 database, added with GlobCorine 2009 database for Europe (Rhone and Po)
* a Readme PDF file for these products.

- Folder "Remote Sensing":

* Maps Snow database, Geotiff 8 bits, WGS84-UTM
* FRAction of snow maps database, Geotiff 8 bits, WGS84-UTM
* Two PDF guidelines for these products

- Folder “Topography”

* DEM of the watershed created by WP 2.3 from SRTM database, 100m resolution, WGS84, Geotiff 16 bits. Chile contains also an added DEM at fine 30m resolution from ASTER database.

2.6 Collaboration with WP3 partners and dissemination

All products provided by our WP 2.3 task are used for scientific application linked with partners of WP3 group. Here is the list of publications at the current date of this D.Data 3.2 report.

J.P. Dedieu, Boos A., Kiage W. and Pellegrini M., 2010. Snow cover retrieval over Rhone and Po river basins from MODIS optical satellite data (2000-2009). *Geophysical Research Abstracts*, Vol. 12, SRef-ID: EGU2010-A-5532.

J.P. Dedieu, Boos A., Kiage W., Pellegrini M., Ravazzani G, Cremonese E., Salandin A. and Finger D. 2010. Retrieval and validation from 10 years of MODIS data for hydrological modelling. Snow cover monitoring in upper Rhone and Po river basins. *PERTH Climate Change and Mountains Conference*, PTHPA-2.5, 185-186.

J.P. Dedieu, Doutreleau V., Lessard-Fontaine A. and Shalpykova G., 2012. Snow cover monitoring in the Kyrgyz Republic through MODIS time series (2000-2010). *Geophysical Research Abstracts*, Vol. 14, SRef-ID: EGU2012-A-1148.

S. Ragettli, Cortes G., McPhee J. and Pellicciotti F., 2012. Modeling hydrological processes under the present and future climate of a high Andean watershed: witch is the appropriate structure? *Alpine Glaciological Meeting*. Zürich, 2012.

J.P. Dedieu, Cremonese E., Diotri F., Busetto L. and Lessard-Fontaine A. Validation of MODIS snow cover images by mean of *in situ* data in the Western Alps. *The Cryosphere*. Submitted 2012.

J.P.Dedieu, Ravazanni G., Pellegrini M., Boscarello L., Lessard-Fontaine A., Salandin A. and Mancini M. Calibration of Hydrological Model FEST from MODIS images in Alpine watersheds; Rhone and Po case study. *Hydrological and Earth System Sciences*. Submitted 2012.