K&C Science Report – Phase 2
Mapping Paleo-Drainage Systems in Northern China using PALSAR

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***Abstract*—Using PALSAR radar on-board the ALOS space platform, we assembled radar mosaics covering three main arid regions in northern China: Taklamakan, Badain Jaran and Hunshandake deserts. They are active deserts which are the main source for sand transported over southern regions in China. The PALSAR L-band sensor allows to map paleo-drainage channels, witness of past and present episodic water flows. We thus observed channel pathways from the surrounding mountains which flow into the desert regions, as the main sediment supply sources. Field work was performed during October 2010 in cooperation with the Institute for Geology and Geophysics of the Chinese Academy of Science. We studied dune and channel formations in the Hunshandake desert, 500 km north of Beijing. Future work will concern the desert regions of Badain Jaran and Taklamakan.**

***Index Terms*—ALOS PALSAR, K&C Initiative, Desert and Water Theme, Northern China, Paleo-drainage channels, deserts.**

I. Introduction

The Kyoto & Carbon Initiative was defined to support data and information needs raised by international environmental conventions, carbon cycle science and conservation of the environment [1]. This initiative is led and coordinated by EORC JAXA, and supported by an international science team. It focuses primarily on defining and optimizing provision of data products and validated thematic information derived from in-situ and satellite sensor data, particularly data acquired by the Phased Array L-band Synthetic Aperture Radar (PALSAR) on-board the Advanced Land Observing Satellite (ALOS) [2]. The Kyoto & Carbon Initiative is based on three coordinated themes relating to global biomes, Forests, Wetlands, Deserts and Water, and a fourth theme dealing with the generation of regional PALSAR mosaics [3].

The access to freshwater resources is a crucial point for future generations, in particular in semi-arid and arid regions on Earth. Currently, typical water prospecting schemes start from existing geological maps, in order to define further fieldwork exploration (geophysical prospecting, drilling). Several pilot projects have shown the usefulness of Earth observation data for generating structural maps that can then be used for water resources prospecting, as for instance the ESA Tiger Initiative [4]. Most of related studies considered space-borne optical data such as LANDSAT to map surface structures in regions where a geological map is not available. A strong limitation of this process is the fact that most of the relevant geological features in arid regions are hidden under a thin layer of aeolian sandy sediments: subsurface geology is then generally invisible for classical optical remote sensing instruments.

Low frequency orbital Synthetic Aperture Radar (SAR) nevertheless has the capability to probe from space the subsurface down to several meters in arid areas. Previous studies have shown that L-band SAR was able to reveal buried and previously unknown paleo-drainage channels in Sahara [5]. During Phase 1 of the Kyoto & Carbon Initiative, we used JERS-1 and PALSAR radar data to build regional and continental scale mosaics of Sahara, that revealed previously unknown geological features such as craters, faults and paleo-rivers [6, 7, 8]. In particular, we mapped a major 1300 km-long paleo-drainage system in eastern Libya, that could have linked the Kufrah Basin to the Mediterranean coast through the Sirt Basin, possibly as far back as the middle Miocene [8]. This result is of highest importance for water resource management in eastern Libya.

Within Phase 2 of the Kyoto & Carbon Initiative, which took place during 2009 and 2010, we focused on the mapping of arid areas in northern China: Taklamakan, Badain Jaran and Hunshandake deserts. They are active deserts which are the main source for sand transported over southern regions in China. The PALSAR L-band sensor allows to map paleo-drainage channels, witness of past and present episodic water flows. This work is being performed in cooperation with the Institute of Geology and Geophysics of the Chinese Academy of Science, Beijing.

II. Deserts in Northern China

Present deserts of northern China mainly distribute between 35°-50°N and 75°-125°E, forming an E-W trending mid-latitude desert belt. The area of desert cover in China is

1,533,000 km^2, that is more than 15% of the whole country [9]. We focused on three main desert areas (see Figure 1). The Taklamakan is one of the largest sandy deserts in the world and covers an area of 270,000 km^2. It is about 1,000 km long by 400 km wide. In recent years, a cross-desert highway was constructed, that links the cities of Hotan (on the southern edge) and Luntai (on the northern edge). The desert expands in some areas, sand enveloping farms and villages as a result of an active desertification process. The Badain Jaran desert in western Inner Mongolia covers an area of 49,000 km^2 and contains some of the tallest sand dunes in the world, reaching 500 m high, juxtaposed with a large number of permanent lakes in the inter-dune depressions [10]. The Hunshundake desert is located north-east of China, between latitudes 42°-44°N and longitudes 112°-118°E, and covers around 21,400 km^2. In this area, the climate is typically controlled by the East-Asian monsoon system, with cold winters and hot summers [11]. Northern deserts in China are likely to have experienced frequent climate change, controlled by monsoon systems, but large uncertainties in our understanding of these changes remain. Large areas in western China were wetlands or less arid between 40 and 30 ka, corresponding to the “Greatest Lake Period” on the adjacent Tibetan Plateau. During the last glacial maximum, some of these Chinese deserts again experienced wetter conditions; however, at the same time the sandy lands in the eastern Chinese desert belt experienced an activation of aeolian dunes. While interpretations of the mid-Holocene environment in the deserts of China are controversial, it is quite likely that it was more humid not only in the eastern areas influenced by monsoon climate systems but also in the western deserts where moisture is currently associated with westerlies [12]. Considering also the fact the deserts in northern China are still active and are the source for aeolian sediments that are further transported to the south, it is then of high importance to better understand their past and present history.

III. PALSAR MAPPING OF PALEO-DRAINAGE SYSTEMS IN NORTHERN CHINA

We used PALSAR dual-pol data to realize mosaics of the three studied region. The largest ones, i.e. Taklamakan and Badain Jaran deserts, were mapped using 50 m resolution PALSAR strips provided within the framework of the K&C project (see Figures 2 and 3). We used a total of 48 strips obtained during acquisition cycle 20 (June – July 2008). The smallest are of Hunshandake desert was mapped using 40 higher resolution PALSAR individual scenes, to produce a final radar map at 12.5 m resolution (see Figure 4).

To process the 50 m resolution PALSAR strips of the Taklamakan and Badain Jaran regions, we used a fully automated data processing chain that we developed during Phase 1 of the K&C Project. It produced a set of 1° x 1° geocoded SAR scenes, that can be superposed to the corresponding 1° x 1° SRTM squares. This data set is managed with the help of a web map server (MapServer), that allows to import and display PALSAR data under Google Earth. The higher resolution PALSAR scenes used to map the Hunshandake desert were individually processed and assembled to produce the geocoded mosaic displayed in Figure 4. It is a single and large radar image that can be displayed under Google Earth, to allow a comparative analysis with Landsat-TM visible data. In cooperation with the Chinese Academy of Sciences, we participated to a study of the dune formation process in the Badain Jaran desert. Our PALSAR mosaic allowed to map channel pathways from the surrounding mountains, which flow into the desert region, as the main sediment supply sources for the large dunes of the Badain Jaran desert [13].

The obtained radar mosaics were also converted into an interactive atlas product, that allows to display 1° x 1° geocoded radar maps, with HydroSHEDS drainage network as overlay (see Figure 5). The HydroSHEDS (Hydrological data based on SHuttle Elevation Derivatives at multiple Scales) data set was computed from SRTM topography data by the USGS, and it provides hydrographic information such as river networks, watershed boundaries and drainage directions [14]. Combining SRTM-derived drainage system to the sub-surface imaging capacities of PALSAR allows to clearly reveal past drainage networks.

IV. FIRST FIELD WORK EXPERIMENT IN THE HUNSHANDAKE DESERT

Within the framework of our cooperation with the Institute of Geology and Geophysics of the Chinese Academy of Science, we participated to a field work experiment in the Hunshandake desert during October 2010.

Two main goals were defined for this field work: 1) Perform some geomorphological studies of past lake structures and 2) Realize some Ground Penetrating Radar (GPR) sounding of young dune formations.

Geomorphological studies of paleo-lakes were conducted with the help of SRTM and PALSAR maps, which allowed us to accurately detect and locate paleo-shorelines. The use of these data on the field, combined to GPS localization, contributed to find several lacustrine sediment outcrops and paelo-shoreline that we could study into details (see Figure 6, top). These observations will help to construct a scenario of past climate conditions in the Hunshandake desert [11, 12].

We also performed some GPR sounding over recent dune fields in the western part of the Hunshandake desert (see Figure 6, bottom), in order to map subsurface structures that are remnants of the dune formation process. Such studies are crucial to model the soil erosion and sand transportation processes, which are key elements of the active desertification taking place in northern China.

Future field work will concern the exploration of Badain Jaran and Taklamakan regions, with the help of PALSAR generated maps to define accurate location of interesting geological features to be studied on the field.

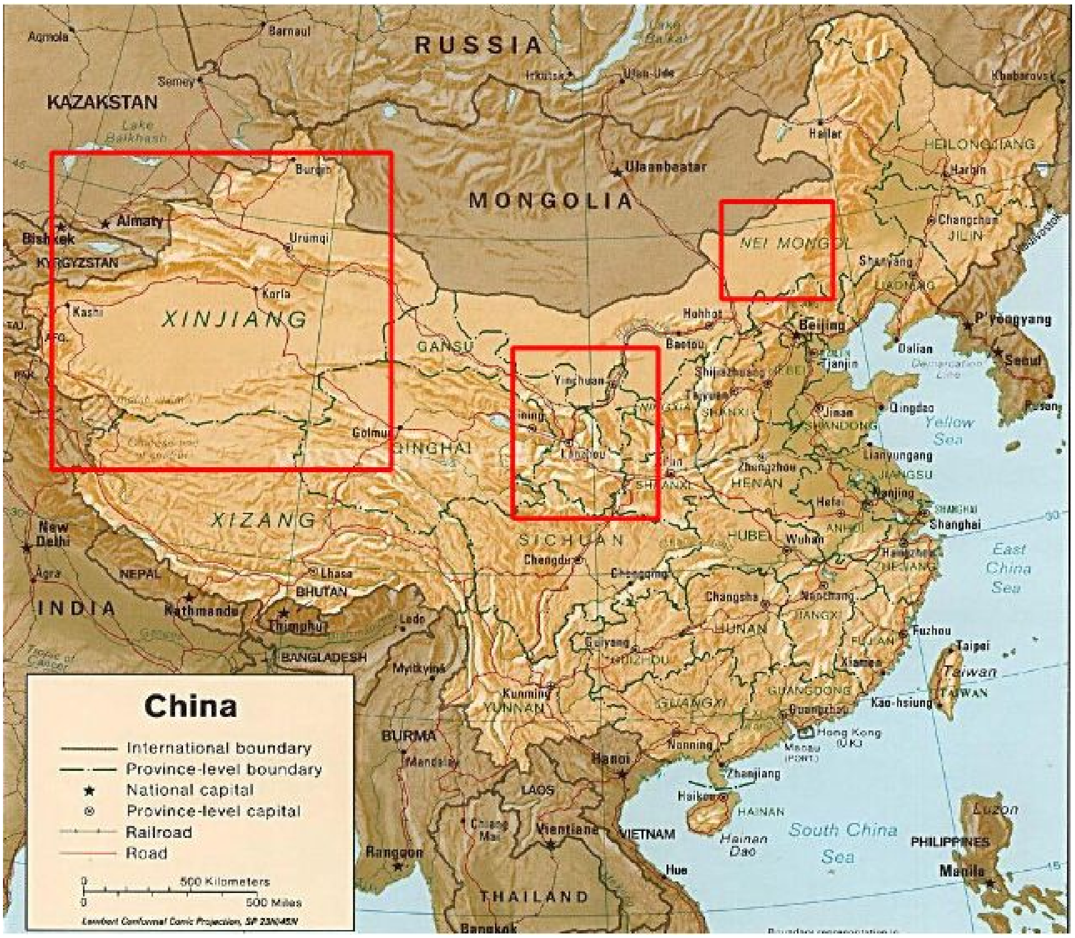

Figure 1. Map of China showing the location of the three studied deserts. From West to East: Taklamakan, Badain Jaran, Hunshandake.

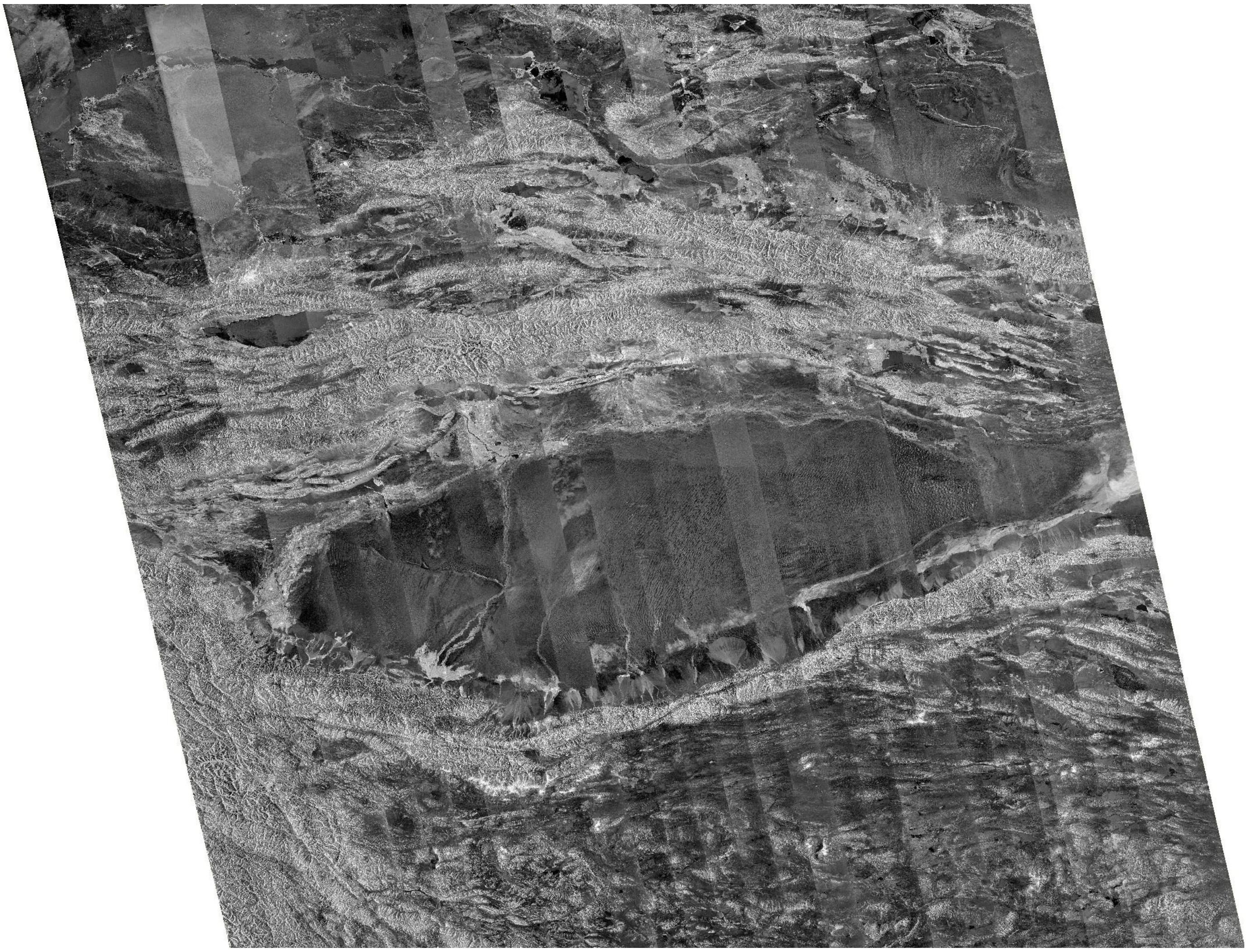

Figure 2. PALSAR mosaic covering the Taklamakan desert (50 m resolution strips).

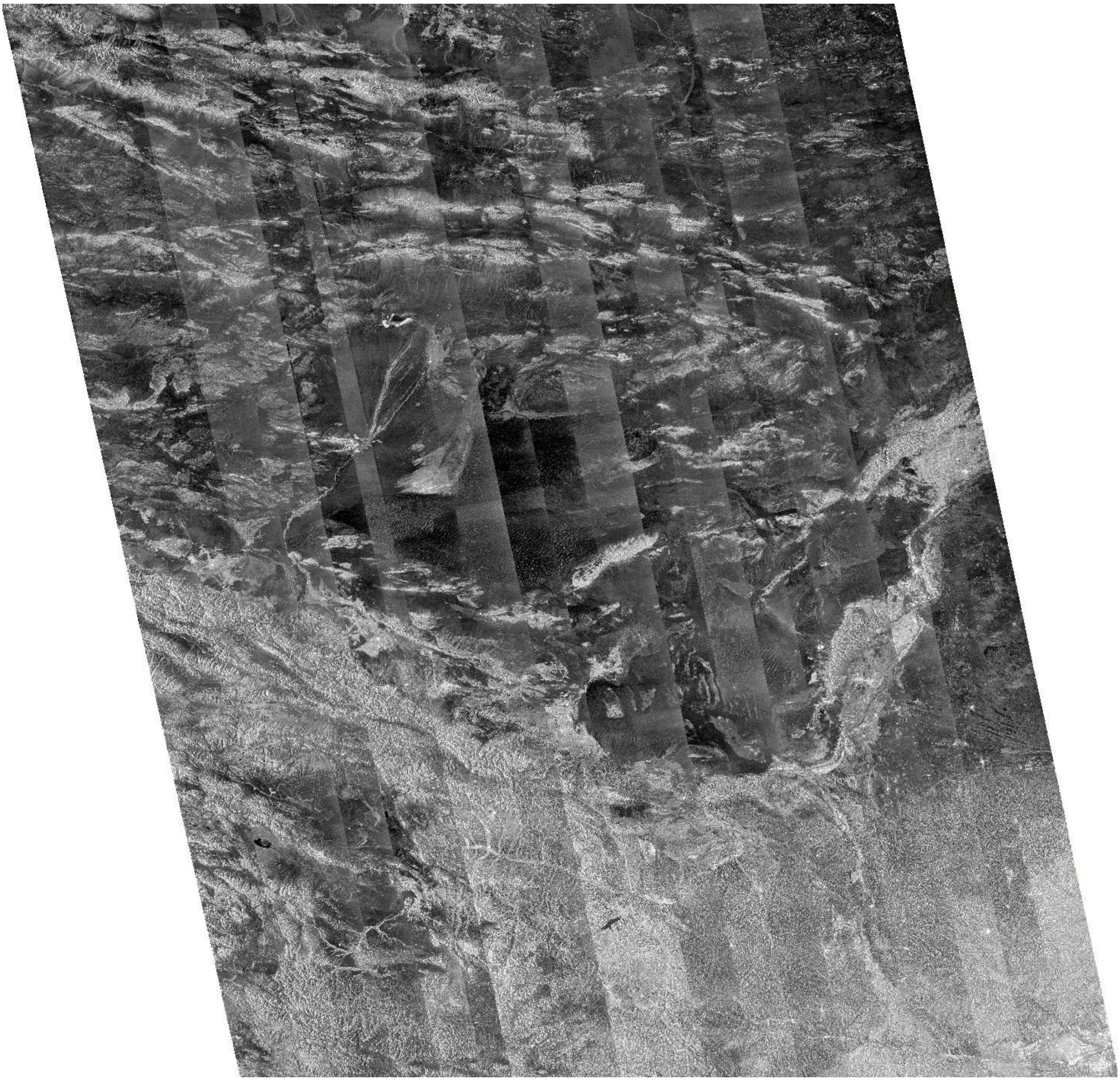

Figure 3. PALSAR mosaic covering the Badain Jaran desert (50 m resolution strips).

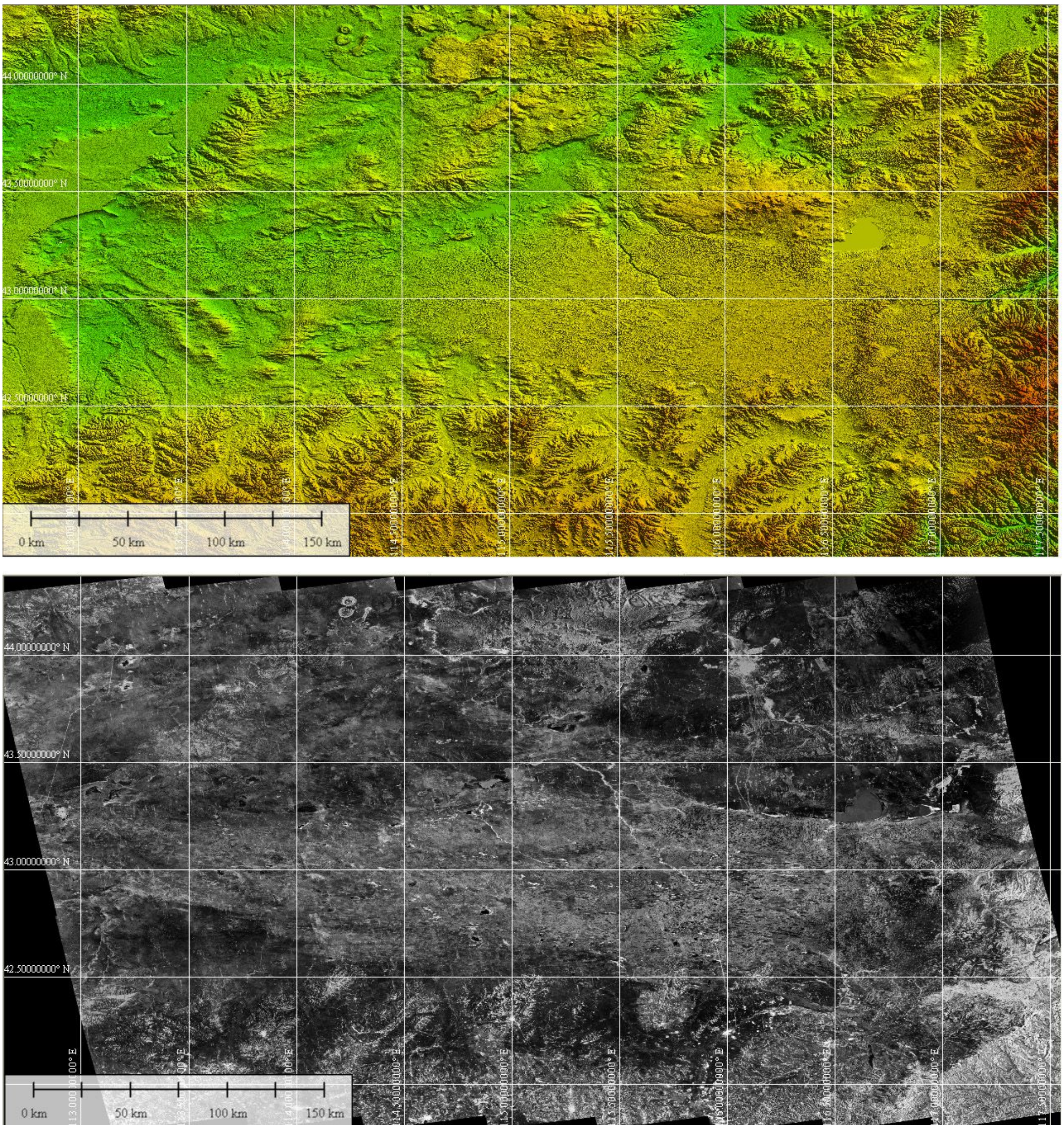

Figure 4. The Hunshandake desert: SRTM coverage (top, 90 m resolution) and PALSAR mosaic (bottom, 12.5 m resolution).

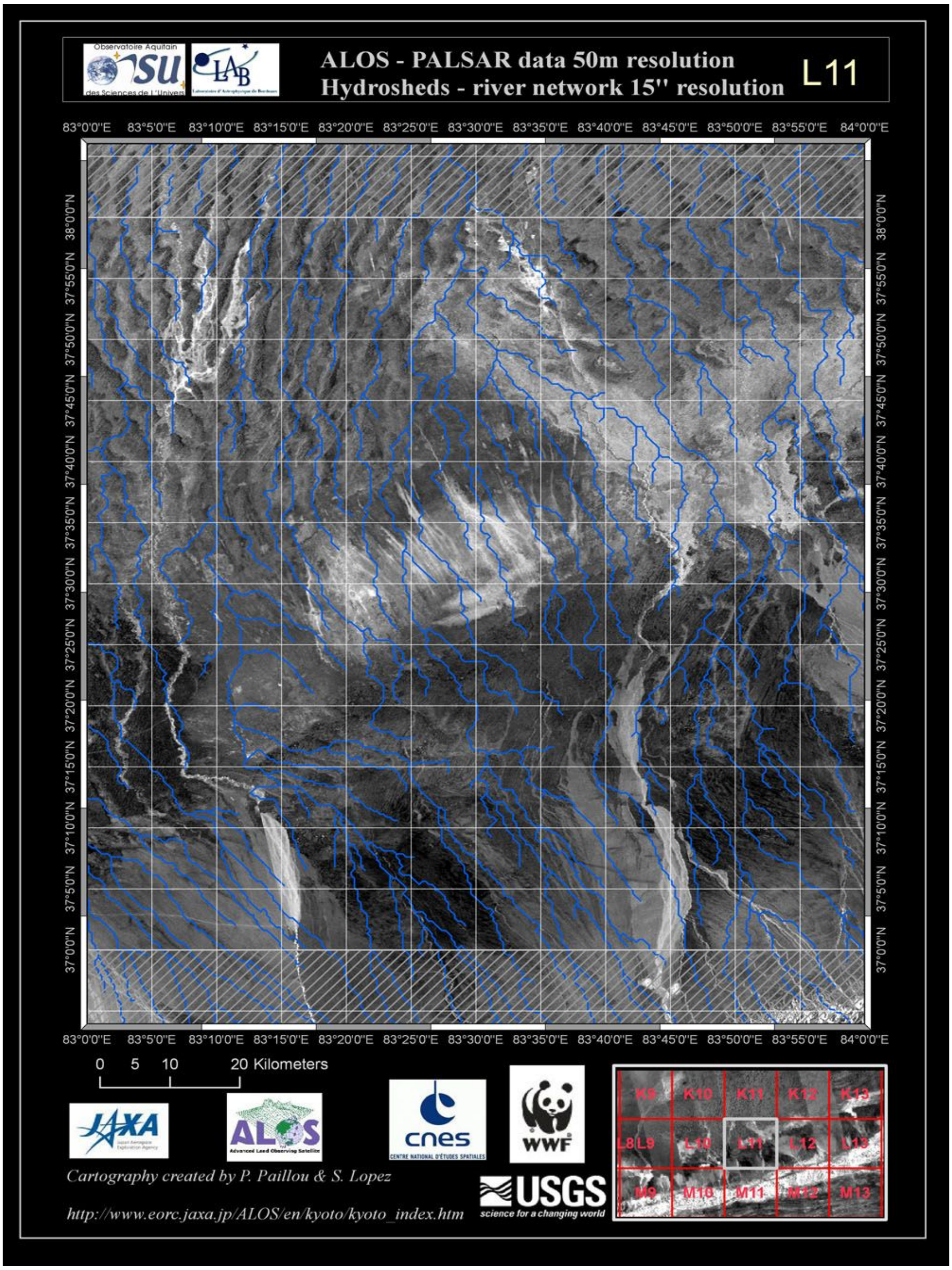

Figure 5. A 1°x1° PALSAR map, part of the generated atlas, with potential paleo-river networks computed from SRTM overlaid.

Figure 6. Top: Lacustrine sediment outcrop that was localized with the help of SRTM and PALSAR data. Bottom: Ground Penetrating Radar sounding of a recent sand dune in the Hunshandake desert.

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References

[1] ALOS Kyoto & Carbon Initaitve home page: http://www.eorc.jaxa.jp/ALOS/kyoto/kyoto_index.htm

[2] Rosenqvist A., Shimada M., Ito N. and Watanabe M. “ALOS PALSAR: A pathfinder mission for global-scale monitoring of the environment,” *IEEE Trans. Geosci. Remote Sens, vol. 45, no. 11, pp. 3307-3316, 2007.*

[3] Rosenqvist A., M. Shimada, R. Lucas, J. Lowry, P. Paillou, B. Chapman [eds.], “The ALOS Kyoto & Carbon Initiative, Science Plan (v.3.1),” JAXA EORC, March, 2008. [Online] Available: http://www.eorc.jaxa.jp/ALOS/kyoto/KC-Science-Plan_v3.1.pdf

[4] The ESA TIGER Initiative, 2005-2008 report, ESA, 47 p., 2009.

[5] McCauley J. F., G. G. Schaber, C. S. Breed, M. J. Grolier, C. V. Haynes, B. Issawi, C. Elachi, R. Blom., “Subsurface valleys and geoarchaeology of the eastern Sahara revealed by Shuttle Radar,” *Science*, vol. 218, pp. 1004-1020, 1982.

[6] Paillou Ph., A. Rosenqvist, J.-M. Malézieux, B. Reynard, T. Farr, E. Heggy, “Discovery of a double impact crater in Libya: The astrobleme of Arkenu,” *C.R. Acad. Sci. Paris, Geoscience*, vol. 335, pp. 1059-1069, 2003.

[7] Paillou Ph., B. Reynard, J.-M. Malézieux, J. Dejax, E. Heggy, P. Rochette, W. U. Reimold, P. Michel, D. Baratoux, Ph. Razin, J.-P. Colin, “An extended field of crater-shaped structures in the Gilf Kebir region – Egypt: Observations and hypotheses about their origin,” *Journal of African Earth Sciences*, vol. 46, pp. 281-299, 2006.

[8] Paillou Ph., M. Schuster, T. Farr, S. Tooth, A. Rosenqvist, S. Lopez, J.-M. Malézieux, “Mapping of a major paleodrainage system in Eastern Libya using orbital imaging Radar: The Kufrah River”, *Earth and Planetary Science Letters*, vol. 277, pp. 327-333, doi: 10.1016/j.epsl.2008.10.029, 2009.

[9] Jimin S., Zongli D., Tungsheng L., “Desert distributions during the glacial maximum and climatic optimum: Example of China”, *Episodes*, vol. 21, no. 1, pp. 28-31, 1998.

[10] Yang X., Ma N., Dong J., Zhu B., Xu B., Ma Z., Liu J., “Recharge to the inter-dune lakes and Holocene climatic changes in the Badain Jaran Desert, western China”, *Quaternary Research*, vol. 73, pp. 10-19, 2010.

[11] Yang X., Zhua B., Wanga X., Lib C., Zhoua Z., Chenc C., Wangd X., Yinc J., Luc Y., “Late Quaternary environmental changes and organic carbon density in the Hunshandake Sandy Land, eastern Inner Mongolia, China”, *Global and Planetary Change*, vol. 61, pp. 70-78, 2008

[12] Yang X., L.A. Scuderi, “Hydrological and climatic changes in deserts of China since the late Pleistocene”, *Quaternary Research*, vol. 73, pp. 1-9, 2010.

[13] Yang X., L. Scuderi, T. Liu, Ph. Paillou, H. Li, J. Dong, B. Zhu, W. Jiang, A. Jochems, G. Weissmann, “Field evidence for multiple factors forming the highest sand dunes on Earth”, *Nature Geoscience*, 2010, submitted.

[14] Lehner B., K. Verdin, A. Jarvis, “New global hydrography derived from spaceborne elevation data,” *EOS Trans*., AGU, vol. 89, no. 10, pp. 93-94, 2008. http://hydrosheds.cr.usgs.gov

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