INVESTIGATING LAND MOVEMENTS OF SALINE SOILS BY SAR BASED METHODOLOGIES

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AGU FALL MEETING 2011
San Francisco, California, USA | 5-9 December
Paper Number: G23A-0825

SALTED SOILS

Solonchaks, more commonly known as saline or salt-affected soils, are a soil variety largely confined to the arid and semi-arid climatic zones. With a total worldwide extent estimated in 2.6-3.4×10^6 km^2, these low-lying areas are characterized by a shallow water table and an evapotranspiration considerably greater than precipitation. Salts dissolved in the soil moisture remain behind after evaporation/transpiration of the water and accumulate at the soil surface.

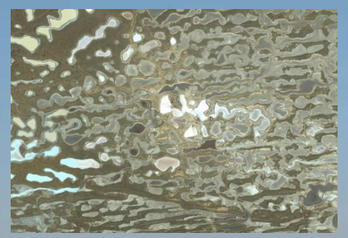


Photo (left) and satellite image (right) of solonchaks in the Caspian area

Solonchak profile, 70 cm deep

Detecting ground displacement by SAR-based methodologies is challenging in these regions. On one hand, solonchaks generally have a stable soil structure because a salt crust is well developed in certain subsoil and climatic conditions and are usually uncultivated. On the other hand, the earth depressions are usually waterlogged due to capillary rise of groundwater and hygroscopic water absorbed by silty particles and salts. Moreover, sparse vegetation is present in these zones even if limited to halophytic shrubs, herbs, and grasses.

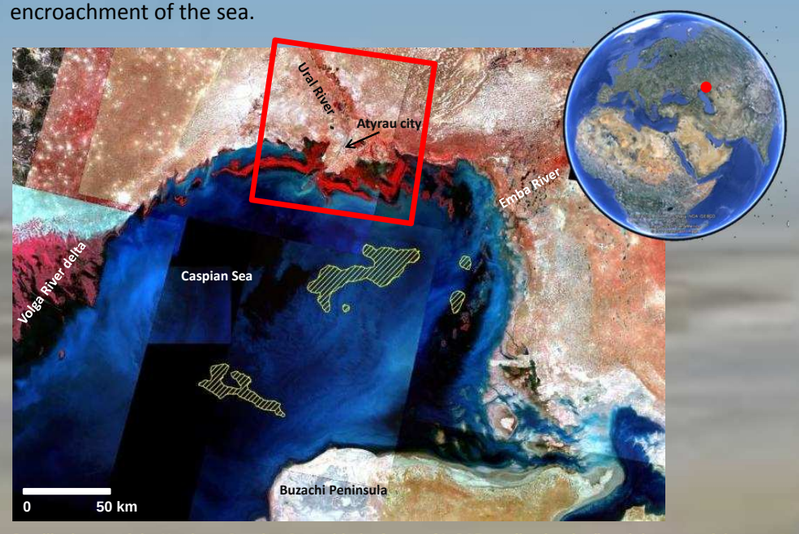
Halophytic vegetation on salted soils along the Kazakh coastal zone

Detail of the "sor" surface

REFERENCES
P. Berardino, G. Fornaro, R. Lanari, E. Sansosti (2002), A new algorithm for surface deformation monitoring based on small baseline differential SAR Interferograms, IEEE Transactions on Geoscience and Remote Sensing, Vol. 40, No. 11, pp. 2375-2383, 2002.
Magagnini L., Teatini P., Strozzi T., Ulazzi E., Simeoni U. (2011), SAR based measurements of land movement in salted-soil regions, Remote Sensing of the Environment, submitted.
Ulmishek F. Gregory (2003), Petroleum Geology and resource of the North Caspian Basin, U.S. Geological Survey Bulletin 2201-B;
Werner, C., U. Wegmuller, T. Strozzi, and A. Wiesmann (2003), Interferometric Point Target Analysis for deformation mapping, paper presented at IGARSS 2003, Inst. of Electr. and Electron. Eng., New York.

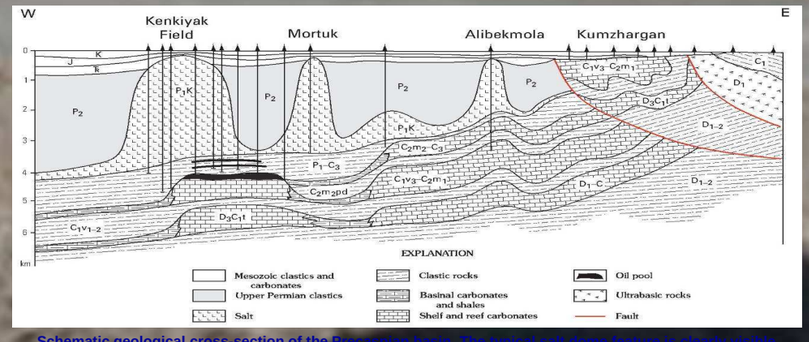
STUDY AREA: COASTAL ZONE OF THE NORTHERN CASPIAN SEA

Although poorly developed, the assessment of land subsidence affecting these territories can be of interest when, as in the northern coast of the Caspian Sea, Kazakhstan, large exploitation of subsurface natural resources are planned in the next future. With a temperature ranging between -25°C and +42 °C and less than 200 mm annual precipitation, saline soils characterize the whole area with the typical morphological feature known as "sor" that is a specific type of depression with solonchak in it. Here, the presence of salt-affected soils is in close relation to the oscillations of the sea level and the massive presence of salt domes of Kungurian age. Due to the extreme flatness of the coastland, on the order of 0.001%, even a small land sinking can produce a significant inland encroachment of the sea.



Satellite image of the Northern Caspian Sea, with the frame of InSAR application (red) and the trace of the major oil fields (yellow). The location of the study area is shown on the top-right inset

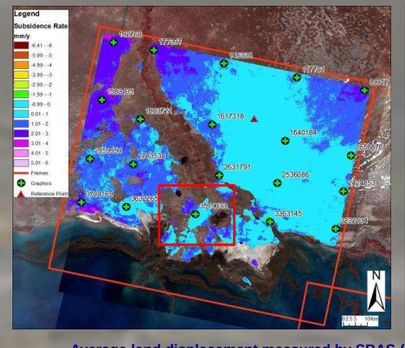
A 2-4 km thick, salt-bearing sequence of the Lower Permian age divides the Caspian depression on sub-salt and above-salt structural–formational complexes. The platform mantle deposits extend from the Quaternary to the Upper Permian deposits in above-salt section and up to the Upper Devonian in sub-salt section (Ulmishek, 2003). Several oilfields were discovered in sub–salt Carbonaceous deposits of the Lower Permian, Middle and Upper Carbon, Upper Devonian stages including Tengiz and Kashagan oil-fields.

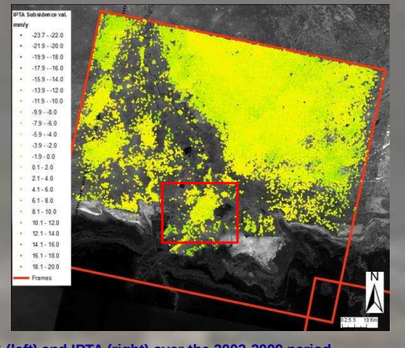


Schematic geological cross-section of the Precaspian basin. The typical salt dome feature is clearly visible

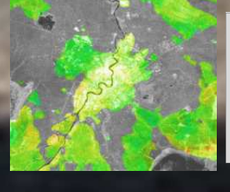
METHODOLOGY: InSAR APPLICATION

Due to the lack of traditional monitoring surveys, SAR-based interferometry represents the unique methodology that can be used to investigate the recent/present ground displacements of this large region. Major land movements are due to oil field development (land subsidence) and salt dome evolution (land uplift). Small BAseline Subset (SBAS) and Interferometric Point Target Analysis (IPTA) have been applied to understand the capability SAR-based techniques of monitoring land displacements in these specific environments. The SBAS approach (Berardino et al., 2002) is developed to maximize the spatial and temporal coherence through the construction of small baseline interferograms. Differently, IPTA (Werner et al, 2003) extracts deformation signals on point radar-bright and radar-phase-stable targets (PT) that are coherent over the entire time interval. We applied the two SAR analyses on a stack of 35 images, 100×100 km wide, acquired by the ENVISAT satellite (Track 464, Frame 2653) from 2003 to 2009 and centred on the Ural River delta. A good coherence of the radar signal has been detected with both the techniques for a large portion of the scene. With SBAS, 123 interferograms with baselines shorter than 200 m have been computed. The quality of the interferograms has been checked and 29 of them characterized by a low coherence due to the presence of wet snow cover have been removed from further processing. With IPTA all acquisitions have been considered. As a consequence of snow-cover and frozen surfaces in winter together with atmospheric disturbances, a large noise level has been detected over the semi-desert areas, also in consideration of an image number at the limit of IPTA applicability. The two methods have provided similar movements in the range of ±4 mm/yr with respect to the reference. Taking into account that the aim of the study is the detection of vertical land movements at frame scale and that the number of available scenes is just sufficient to perform a PT investigation, the results obtained confirm that IPTA approach is successfully applicable but the traditional multi-baseline interferometry is a more robust approach for the analysis of the subsidence on this kind of soil.

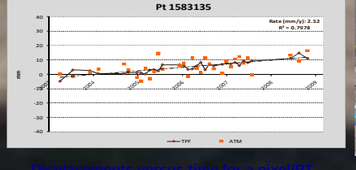




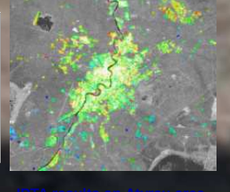
Average land displacement measured by SBAS (left) and IPTA (right) over the 2003-2009 period



SBAS results on Atyrau area



Displacements versus time for a pixel/PT detected by SBAS and IPTA, respectively



IPTA results on Atyrau area