Probing Fossil Aquifers Using Airborne Sounding Radars

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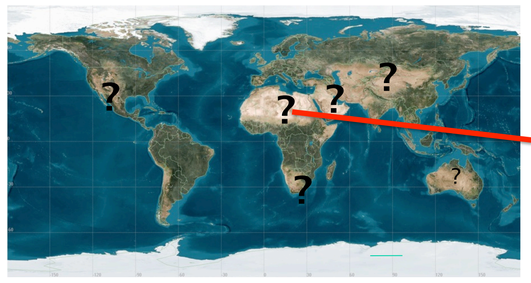
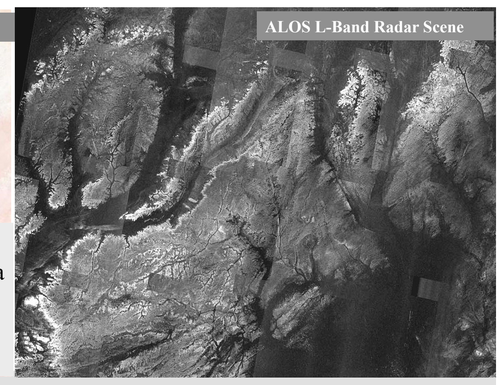
National Aeronautics and Space Administration

Project Objectives:

Explore the ability of Low Frequency airborne sounding radar to probe shallow fossil aquifers in Hyper-Arid environments and map the variation in the depth of the water table at 4 m vertical resolution to understand the aquifers recharge and discharge dynamics. The success of the method will open a whole new potential of exploring and monitoring shallow aquifers on a large scale in earth and on future planetary missions.



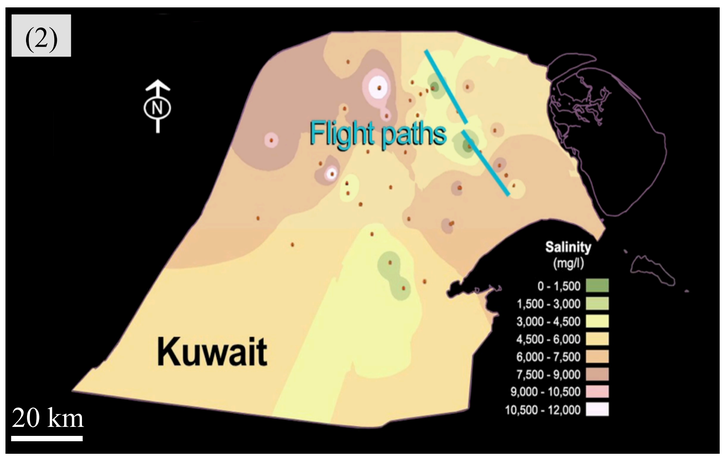


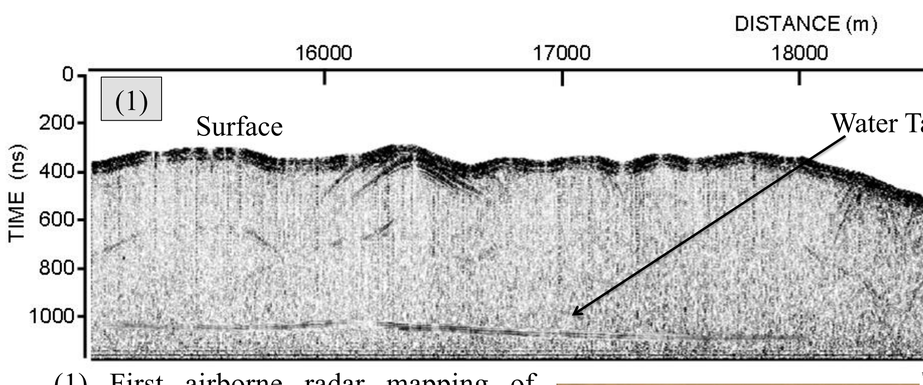
Buried drainage networks in the Sahara attest the climatic change that these areas went through

Major Science Questions of the Carried Investigation

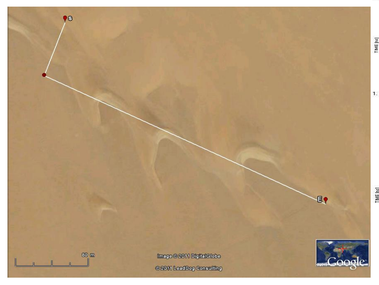
- ***What were the paleo-climatic conditions of the earth arid environments and how can they be used to understand the current climate trends on large scales***
- ***What are the aquifer boundaries in the desertic regions of the earth and how we can use them to understand groundwater recharge and dynamic?***

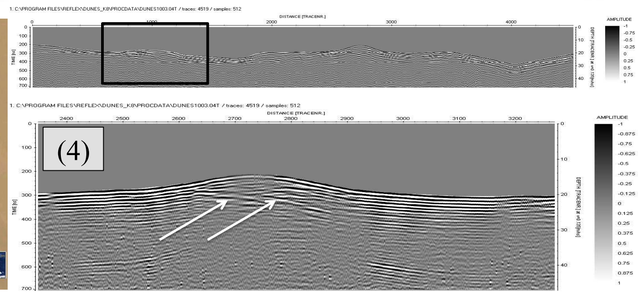
FY11/12 Results:





(1) First airborne radar mapping of subsurface Aquifer in a hyper-arid environments: 40 MHz radargram of the Rawdateen Aquifer in Northern Kuwait, showing the depth variation in the water table at 30-45m deep. The profile is 5 km long and water table is represented as the flat linear reflector occurring at 1000 ns range delay. (2) Helicopter Flights path over northern Kuwait. (3) N3 Dolphin Helicopter and the Investigation team.



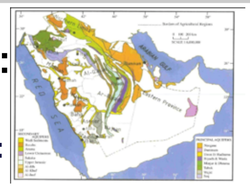


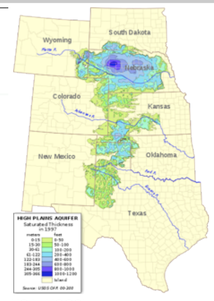
(4) Probing inner structure of the Dune field in Northern Kuwait to understand paleo-wind regimes that contributed to the precipitations that formed the aquifers

Benefits to NASA and JPL:

(1) New Science Endeavor on the Characterizations of Fossil Aquifers: Why it matters ?

- **Several hypothesis for their origin and evolution awaiting for validation: (locally formed by meteoritic recharge or underground water transport)**
- **Unexplored potential to understand earth paleoclimate: *only Lake Vostok has benefit from such link***
- **The depth variation of the water table and its correlation to surface topography is an crucial to understand recharge, ground water transport processes and origin of the aquifer recharge that correlate to the paleo-climatic condition.**
- **There approximate number, occurrence and distribution remain largely unknown.**
- **The delineation of fossil aquifers is largely unknown.**
- **Often studied to mitigate seasonal or temporal dry outs.**





(Ogallala, USA, USGS)

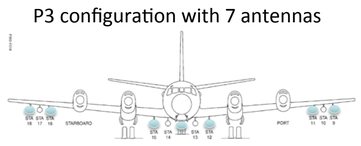
(Nubian Aquifer, HEINL & BRINKMANN, 1987)

(2) New Mission and Airborne Opportunities for one the Earth Least Studied Areas

Desert Subsurface Exploration of Aquifers-Desert SEA: Dual-Band Low Frequency Airborne Exploration

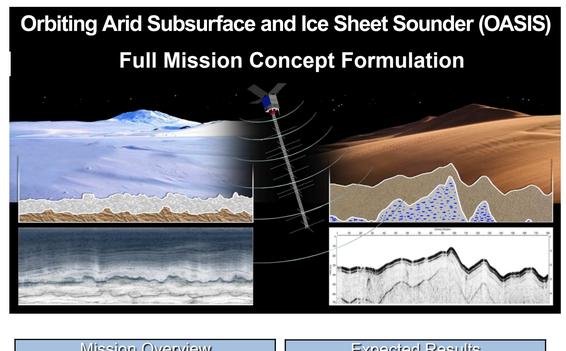
	Regional survey at 1000 m altitude	Local survey at 200 m altitude
Platform	Air Force P3	Air Force Dauphine helicopter
Number of antennas	7 for the suppression of off-nadir surface scattering (clutter)	2 for bi-static measurement
Primary operating frequency	40 MHz for deep penetration 75 MHz for high vertical resolution	
Operating mode	Chirp or pulse	
Bandwidth at center frequency	20 MHz at 40 MHz 40 MHz at 75 MHz	

P3 configuration with 7 antennas



Dauphine with 2 antennas

Space Act Agreement Between NASA & KISR in Negotiation



Mission Overview

1. The first global survey of ice sheets and arid desert
2. Launch near solar minimum
3. Initial orbit altitude 400 km, decaying to 250 km at the end of the mission
4. Mission period: 18 months
5. 4 AM / 4 PM sun-synchronous polar orbit

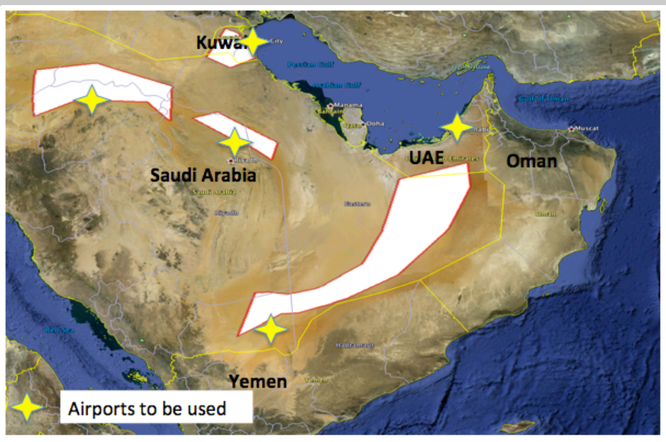
Radar Instrument

A space borne 50MHz sounding radar will have an average penetration of 2 km in ice sheets and 100 m in dry desert sediments.

Expected Results

1) **Determine ice sheet volumes, thicknesses, basal topography and discharge rates to substantially reduce the uncertainties in current model projections of future ice mass balance and its effect on sea level rise in a changing climate.**

2) **Determine the occurrence and spatial distribution of shallow aquifers in the most arid desert regions on Earth to understand ground water hydrology, enhance ground water flow models and provide new insights into available water resources and recent paleo-climate changes.**



(5). The Dammam Aquifer and Empty Quarter areas to be surveyed by Desert-SEA. White areas indicate planned flight areas. ***Flight velocity*** *= 500 km/hr (270 knots),* ***Swath*** *= 1.15 km with 10% overlap,10 km gap between swaths,* ***Total operation hours:*** *135 (18 flights P3-C) + 90 (30 flights, Dauphin N3)*

Acknowledgements: **We would like to acknowledge the Kuwait Institute of Scientific Research for their support to the radar integration onboard the Kuwaiti Air force Helicopter and for their scientific contribution in the data analysis and ground validation.**

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National Aeronautics and Space Administration

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Publications:

(1) Heggy et al., 2011, Probing Shallow Aquifers in Northern Kuwait Using Airborne Sounding Radars, Abstract P13G-06, presented at 2011 Fall Meeting, AGU, San Francisco, Calif., 5-9 Dec.

(2) Heggy, Fadlemawla, Avouac, Al-Rashed, Normand, Sultan et al., 2012, Exploring Fossil Aquifers Using Sounding Radars: Implication to Understand large-scale Ground Water Dynamic and Desert Paleo-Climatic conditions. In preparation for GRL submission planned for early November 2012.

Presentations and invited talks:

The outcome of this research has been subject to several oral and invited talks by The Lunar and Planetary Institute (USA), American Geophysical Union fall meeting (USA), University of Western Michigan (USA), University of Paris VII (France), University of Dresden (Germany), Qatar Foundation (Qatar), Kuwait Foundation (Kuwait), Kuwait Institute for Scientific Research (Kuwait), USAID-Washington (USA). NASA has also announced the results of the experiment in formal press release that has been widely diffused in public media.

Poster No. DR-4