Abstract

The Gulf Coast is a major source of oil and gas for the United States. In Texas, an oil field over a salt dome known as Spindletop started the Texas Oil Boom. Salt domes are great traps because they are mostly impermeable and create an upward structure for oil and gas to accumulate. Several salt domes have been documented in and around the Houston area such as Pierce Junction, Mykawa, and Webster to name a few. The diapirism of the salt domes can be attributed to regional extension and sedimentation. Monitoring the topographical changes directly above salt domes can give insight to subsurface movements of the salt. Geographic Information System (GIS) and remote sensing techniques are used to quantify surface movements of the salt domes in the Houston area. Data collected by Light Detection and Ranging (LiDAR) and Global Positioning System (GPS) allow detection of surface changes on a centimeter to millimeter scale. Preliminary statistical analysis of Digital Elevation Models (DEM) over a span of 12 years (1996, 2001, and 2008) showed increased surface changes over some salt dome locations. GPS studies from Engelkemeir (2008) and the Harris-Galveston Subsidence District (HGSD) show most of Houston is subsiding. Areas that are not subsiding or rising are mostly over known salt dome locations. Gravity surveys will be conducted over these areas to ensure that it is salt under these areas. Areas over salt domes should have a significantly different reading compared to areas without a salt dome. Quantitatively tracking surface movements of salt domes can be an easier and cheaper alternative to subsurface monitoring. Variations or abnormal movements may signify regional tectonic activity.
Introduction
Surface deformation has been an ongoing problem in the Houston Metropolitan area because of the city's location in a passive margin where burial and subsidence are common. According to previous studies the sources of the surface deformation are typically attributed to anthropogenic activities, mainly the subsurface withdrawal of oil, gas, and groundwater. However, the majority of the studies done have not accounted for the vast amount of withdrawals in the Houston area and its role in the surface deformation. The objective of the study was to identify areas of surface deformation in the greater Houston area and their possible relationship with anthropogenic salt movements. To accomplish this integrated three kinds of data: (1) GPS LiDAR, (2) LIDAR data, and (3) gravity data. The GPS data was used to identify the location of salt withdrawal areas. The LIDAR data was used to identify the location of salt withdrawal areas. The LIDAR revealed changes between salt domes and their surrounding areas. TLS data collected over the Pioneer Junction salt dome also revealed changes in the subsurface. Groundwater withdrawal may have a large influence on the surface deformation of the Houston area, but salt related deformation should be seen simply because of quantity influence.

Methods
DEM Height Computation
The polygon technique used by Engelnear (2000) was employed to examine changes between the centers of the salt dome relative to its surrounding areas. For each polygon the average elevation within is calculated with a local polynomial regression and the average elevation is multiplied with the cell size of the DEM to get the elevation change and an acceptable measure of the elevation (Engelnear, 2000). Five polygons were created for each salt dome location outside polygons surrounding the salt dome on the north, south, east, and west. One polygon was created within the area of the salt dome. The polygons were created to avoid artifacts within the DEM.

GDS Velocity
GDS data is currently collected continuously by The Harris-Galveston Subsidence District (HGSB) and National Oceanic and Atmospheric Administration (NOAA) with a mean elevation rate for areas one (8.4 MG D ), two (36.9 MGD), and three (195.5 MG D ) in Harris-Galveston Subsidence District. (Figures 7).

GDS Velocity Results
The study area was extensively covered by salt withdrawal and domes in the salt range. Salt withdrawal over the crest of the salt dome. Two sets of surveys were conducted at two various times.

Conclusions
GPS, LIDAR, and gravity are all powerful tools. The GPS data documented substantial subsidence and uplift in the Houston area. These surface deformations may suggest continued salt withdrawal and salt diapirism. DEM derived from LIDAR documented elevation change between areas within the salt domes and their surroundings. This could suggest salt movement, possibly the result of secondary salt withdrawal during diapirism. The changes in the gravity measurements could be another indicator of subsurface salt movements. Although salt withdrawal and salt diapirism could cause the observed results another large factor comes into question: groundwater. Groundwater withdrawal has been targeted as one of the main causes of subsidence in the Houston area for decades. This extremely impactful anthropogenic factor may slow to none or not surface deformation is in the greater Houston area. Natural factors that may influence subsidence such as salt withdrawal may be largely overshadowed by groundwater withdrawals.

References
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