**Chapter 6 - Conclusions and Future Works**

**6.1 Conclusions**

This dissertation presents three studies of using satellite geodesy technique to study environmental and global change. The main conclusions from the three studies (Chapter Three, Four and Five) are summarized in below respectively.

Chapter Three shows that the short-term annual variation of coastal uplift measured by GPS is useful in studying spatial and temporal changes in mass loss of the Greenland ice sheet. Anomalously large uplift is observed at most GPS sites in 2010, indicating significant ice mass loss in 2010. Comparison between GPS data and climatic data shows that the 2010 anomalous melting is caused by a combination of warm air and warm sub-surface ocean water. What’s more, this study shows that the Irminger Current, a warm subsurface current, plays an important role in “shaping” the spatial pattern of coastal melting: the amount of ice mass loss decreases generally along the pathway of Irminger Current (from southeastern to southern and then southwestern Greenland, reaching about 69 ° N in 2010).

Chapter Four shows that accelerated melting of the Greenland ice sheet can in turn influence the regional ocean. Recent freshwater flux from Greenland is estimated using GRACE gravity data. Freshwater flux from Greenland, Canadian Arctic Archipelago and Arctic sea ice increases by 20 mSv from the mid – late 1990s to 2013 and at least 70 percent of the increase winds up in the Labrador Sea due to the clockwise nature of ocean circulation around Greenland. This study shows that a rapidly decline in Labrador Sea Water thickness (and density) coincided with a rapidly increase in the freshwater flux into the Labrador Sea, while the salt flux into the region remained increasing. This suggests that recent accelerated melting of the Greenland ice sheet starts to reduce the formation of Labrador Sea Water and potentially weaken the AMOC.

Chapter Five shows that using InSAR technique to monitor surface deformation is promising to monitor pressure change in deep reservoir. Up to 10 cm surface uplift between January 2007 and March 2011 is observed at a CO2-EOR field in Scurry County, West Texas. Monthly injection and production data and an analytical model are utilized to estimate the pressure change in the reservoir and to investigate the causes of the observed uplift. This study shows that net CO2 injection results in up to 12 MPa pressure buildup in the reservoir, the major contributor to the observed surface uplift.

**6.2 Future Works**

In Chapter Three, the GPS data are collected and processed up till 2011. This study shows extreme ice mass loss in 2010, while later studies show that ice mass loss in 2012 and 2015 exceeded the one in 2010 [e.g., Hanna et al., 2014; Tedesco et al., 2015]. Thus, it is helpful to update the analysis to continuously monitor the annual variations of ice mass loss in coastal Greenland. Longer observations allow for the correlation analysis between annual uplift and climatic factors. What’s more, only short-term elastic crustal response to current mass loss and long-term viscous crustal response to past ice mass loss are considered in the model. Other studies revealed that short-term viscous response to present-day ice mass change should be considered in order to better interpret coastal uplift in Greenland [e.g., Nield et al., 2013]. One long-term GPS station KULU is near Helheim Glacier and KULU GPS time series shows non-linear uplift since 2003. The rapid speed up and a subsequent slow-down behavior are well known from various types of data for Helheim Glacier [Howat et al., 2005; Nick et al., 2009], which is probably a big source of the KULU uplift. Thus, it seems an over-simplification to simply fit a constant acceleration model to KULU GPS time series. Therefore, using ice-mass change record and a viscoelastic model could better explain the non-linear uplift.

In Chapter Four, the freshwater flux estimate is a minimum estimate and we focus on three sources that are likely to influence Labrador Sea convection and can be estimated by remote techniques: the Greenland Ice Sheet, glaciers in the Canadian Arctic Archipelago and changes in Arctic sea ice. Other sources such as precipitation minus evaporation, oceanic transport and the melt water from annual freeze-thaw cycle of Arctic Sea ice also contribute to the Arctic freshwater budget. Thus, besides remote technique, in situ measurement network is required to better measure the Arctic freshwater budget. Using chemical tracers can help to investigate the pathways of freshwater and distinguish freshwater with different origins [Haine et al., 2015]. This study suggests that at least 70% of Arctic freshwater flux ends up in the Labrador Sea, reducing the formation of Labrador Sea Water, hence weakening the AMOC. This hypothesis can be validated by sophisticated hosing experiments that allow freshwater flux being focused into the Labrador Sea and investigate its effect on the AMOC.

In Chapter Five, I show that InSAR-monitored surface deformation can be an indicator of reservoir pressure change. However, better knowledge about the Young’s modulus is required to more quantitatively link surface deformation and reservoir pressure. Thus, independent determination of Young’s modulus from down-hole measurements or other methods is suggested for future work.