論文の内容の要旨

Integrated Climate Change Impact Assessment and Extreme Event Forecasting in the Lake Victoria Basin(LVB)

（ビクトリア湖流域における統合的な気候変動影響評価と極端事象の予測）

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Extreme weather events have been the leading cause of disasters and damage all over the world. Recent events have led to mass displacement, loss of income, and hampered access to clean water and health to many. The primary ingredient to these disasters especially floods is rainfall which over the years, despite advances in modeling, computing power and use of new data and technologies, has proven to be difficult to predict. Numerical weather prediction (NWP) and climate models using global forecasts and emission scenarios as initial and boundary conditions have provided short to midterm forecasts and climate projections in many parts of the world. The Lake Victoria Basin (LVB) in East Africa supports over three million livelihoods and hosts the world record for elaboration of vertebrate species diversity, species extinctions, and exotic species invasions. The second largest freshwater lake in the world is a valuable resource to five East African countries as a source of water and means of transport. However, with a Mesoscale climate regime driven by land and lake dynamics, extreme Mesoscale events have been prevalent and the region has been on the receiving end during anomalously wet years in the region. This has resulted in loss of lives, displacements, and food insecurity. As an essential aspect of early warning there is a need to strengthen adaptation through improved prediction of rainfall and floods.

It is now more evident than ever that climate change will have adverse impacts on the global population in coming years. Since the release of Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report: Climate Change 2007 (AR4) in 2007, it has been shown that impacts of climate change are already being felt, with increases in sea level rise, retreating glaciers and more frequent weather extremes. In the LVB, the effects of climate change are increasingly being recognized as a significant contributor to poverty, by its linkage to agriculture, food security and water resources. One aspect that is investigated widely with respect to climate change is the impacts it will have on extreme weather events. There is a general consensus that changes in frequency and intensity of extreme weather and climate events will have adverse effects on both humanity and nature.

Adaptation to climate change needs an understanding of climate change impacts at local scales. There is a need to connect the global scale projections with impacts it may have on people through downscaling and other means. The LVB is a regional basin with multiple land uses and water resource needs. In addition, it is one of the basins that have been heavily affected by extreme weather, especially storm-induced floods. Of particular importance are the likely impacts of climate change in frequency and intensity of extreme events. To tackle this aspect, this study adopted an integrated regional, mesoscale and basin scale approach to climate change assessment. The study investigated the projected changes in mean climate over East Africa, diagnosed the signals of climate change in the atmosphere, and transferred this understanding to mesoscale and basin scale. Changes in rainfall were analyzed and similar to the IPCC AR4 report; the selected three General Circulation Models (GCMs) project a wetter East Africa with intermittent dry periods in June-August.

The highest projected changes are in the October-December season whose variability is closely linked to inter-annual variability of sea surface temperature anomalies in the Indian Ocean. Weakening of the Walker circulation, anomalous monsoons, and moisture advection into East Africa in the two seasons are some of the phenomena associated with increased rainfall. Investigation on the Nino3 sea surface temperature (SST) anomaly index reveals an increasing trend with the selected target period of study projected to experience increased frequency of El-Niño/Nina events. GCMs projections for the past (1981-2000) and future (2045-2065) were bias corrected and projected changes at a river basin scale investigated. In the Nyando river basin, a perennial flood basin, the selected three GCMs project a wetter future with extreme events occurring almost two times the magnitude of the past climate. The trend by the three GCMs is the same; increased flood probability in the future and about 10-20% increase in mean discharge.

In addition to climate change assessment; the study also focused on short-term weather forecasting as a step towards adapting to a changing climate. This involved dynamic downscaling of global weather forecasts to high resolution with a special focus on extreme events. The skill of operational weather forecasts has increased over the last five decades. This improvement has taken place gradually and relatively steadily; driven by advances in scientific understanding of physical processes and rapidly increasing computational resource developments. The last decade has seen remarkable progress in exploring satellite observations especially microwave measurements and the launching of new platforms. Numerical weather prediction and assimilation satellite data in the microwave band has been shown to improve predictability. In this tropical inland lake basin with a sizeable water body and locally controlled Mesoscale weather system; an improved prediction would be greatly useful for flood early warning and water resources management.

By utilizing complex model dynamics, the system was able to reproduce the Mesoscale dynamics well, simulated the land/lake breeze and diurnal pattern but was inadequate in some aspects. The quantitative prediction of rainfall was inaccurate with overestimation and misplacement but with reasonable occurrence. This was a remarkable improvement compared to the coarse resolution of 100km which had not factored in local scale dynamics induced by the land-lake interaction and low-high altitude contrast in this region. To address these shortcomings this thesis investigated the value added by assimilating Advanced Microwave Scanning Radiometer (AMSR-E) brightness temperature during the event. By assimilating 23GHz (sensitive to water) and 89GHz (sensitive to cloud) frequency brightness temperature; the predictability of an extreme rain weather event was investigated. The assimilation of AMSR-E brightness temperature through a Cloud Microphysics Data Assimilation (CMDAS) into the weather prediction model considerably improved the spatial distribution of this event.

Data assimilation improved the simulation of the rain event by more than 50% with the spatial location of maxima at 00hrs and 03hrs after assimilation matching Tropical Rainfall Measuring Mission (TRMM). In addition, overestimation of rainfall predicted by the NWP (without data assimilation) was reduced considerably. The assimilation of brightness temperature is implemented through a Radiative transfer model (RTM). The RTM involves the calculation of the surface emissions, scattering and absorption of passive microwave energy on soil, land surface and the atmosphere. A key component of this determination is the computation of surface emissivity which is derived from surface temperature. Results in this region showed that the NWP had a tendency to overestimate surface temperature which in turn affected the assimilated brightness temperature. This had the negative impact of reduced water vapor in the system and the model could not keep the induced model state for long. Sensitivity experiments conducted by subtracting 2-10K from the surface temperature at the assimilation time showed that changes in the amount of water vapor corresponded to the magnitude of temperature change. This highlighted the uncertainty in water vapor assimilation due to model errors in estimation of surface temperature. This study identified this challenge and proposes a major validation / improvement of the RTM.

The downscaled/predicted quantitative rainfall was then assessed for its suitability as an input to a decision making process with respect to floods. Hydrological modeling using the QPF from the NWP showed promising flood simulation results even though there was a tendency to overestimate flow. Nonetheless, it shows a potential for future application as an input to an early warning system.