UNIVERSITIES DENMARK

BUILDING STRONGER UNIVERSITIES
ENVIRONMENT AND CLIMATE

DANSKE UNIVERSITETER
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PhD Proposal Plan (Refined)

1. Name of the PhD student

Akwasi Afrifa Acheampong.

2. Project working title

Monitoring and Predicting Climate Variability by Estimating Total Electron Content and Integrated Water Vapor from GNSS Base Stations in Ghana.

3. Abstract

Human existence and our quest to adapt comfortably to the natural environment are impacting greatly on atmospheric conditions and weather patterns. The ultimate challenge for researchers and scientists is to appreciate the processes that determine the state of the climate and possible ways that might have influence this change in the past and/or will be in the future.

Climatic studies and predictions use models developed by studying energy transfer from the sun to the Earth and the changes in the composition and motion of the Earth's atmosphere. The models are based on timescales ranging from seasonal to centennial using fluctuations resulting from natural and man-made interactions between the oceans, atmosphere, land, cryosphere, volcanic eruptions and variations in the sun's intensity. These atmospheric interactions when modeled correctly will provide future climatic simulations to enhance our understanding of climate-relevant processes for further studies and predictions.

The intent of this study is to monitor current climatic activities and predict future changes in the climate of Ghana using techniques and concepts of GNSS meteorology, Data Assimilation and Parameterization in addition to surface variables.

4. Project background (including state-of-the-art)

Human existence and our quest to adapt comfortably to the natural environment are impacting greatly on atmospheric conditions and weather patterns. The ultimate challenge for researchers and scientists is to appreciate the processes that determine the state of the climate and possible ways that might have influence this change in the past and/or will be in the future. Climatic studies and predictions use models based on systems of differential equations that considers a 3D grid over the surface in question. Results are evaluated by studying how interactions between the atmosphere, oceans, land, living things, ice, and energy from the Sun affect each other. climatic conditions are modeled using winds, heat transfer, radiation, relative humidity, and surface hydrology as parameters, and these models can further be used to describe vividly rising earth surface temperature, increasing greenhouse gases and decreasing ice (Wikipedia, 2012; Soos, 2010; Gardner, 2007).

Climatic models are developed by studying energy transfer from the sun to the Earth and the changes in the composition and motion of the Earth's atmosphere. These developments are fully consistent with approaches being taken in other fields of science dealing with very complex systems. The models are based on timescales ranging from seasonal to centennial using fluctuations resulting from natural and man-made interactions between the oceans, atmosphere, land, cryosphere, volcanic eruptions and variations in the sun's intensity (McGuffie and Henderson-Sellers, 2005). These climate simulations provide a framework within which enhanced understanding of climate-relevant processes, along with improved observations, are merged into coherent projections for studies and predictions (CCSP, 2008).

The intent of this study is to monitor current climatic activities and predict future changes in the climate of Ghana using techniques and concepts of GNSS meteorology, Data Assimilation and Parameterization in addition to surface variables.

5. Hypothesis/aim of project

The main aim of this project is to develop a Prediction Model by Adapting General Circulation Models using Data Assimilation and Parameterization Schemes based on ground-based GNSS Data and surface measurements in Ghana. This study will seek to achieve these objectives:

- Set-up a Base Station to serve as Master Control Station for logging and archiving GNSS Observational Data;
- Assess current Numerical Weather Prediction Models used by Ghana Metro Office;
- Review General Circulation Models their progress, prospects and challenges for Local-scale use and
- Evaluate and demonstrate data exploitation techniques and schemes needed for Numerical Weather Prediction and climatic applications

6. Project description

Justification…

Climate scientists study how the climate behaves and how it may change in the future; their findings provide us with an understanding of how our actions now will affect the future of our planet. They model the statistics of the weather against time variability on different timescales and spectrum. The resultant models are complex computer simulations of earth systems for investigating climatological theories and offer the most effective means of answering questions requiring predictions of the future climate and of potential impacts of climate changes (Pipitone, 2010 & McGuffie and Henderson-Sellers, 2005).

To unravel the dynamics of the climate system an analysis of observed data and experimentation with climate models of varying complexity operating globally or in limited regions are used (von Storch, 2005). Climate models come in varying flavours based on the level of complexity with which they capture various physical processes or physical extents with Global Climate Models or General Circulation Models (GCMs) being the most sophisticated of climate models. They are numerical simulations that attempt to capture as many climate processes as possible with as much detailed output as possible (Pipitone, 2010; McGuffie and Henderson-Sellers, 2005; Shackley et al, 1998). Whilst GCMs may aspire to be the most physically accurate of models by showing agreement in the projected global and continental temperature trends in the 21st century, there is large disagreement in the projections of precipitation at the regional scale and the spatial resolution is often not sufficient to fulfill the requirements of highly resolved regional information (Dobler, 2010; Dobler and Ahrens, 2008; Annamalai et al., 2007).

To adapt the GCMs and refine their spatial resolutions GNSS meteorological concepts will be used. GNSS Base stations integrated with atmospheric sensor equipment is capable of making thousands of accurate upper and lower atmospheric measurements daily for numerical weather forecasting, atmospheric research, precipitation, space weather applications and geomagnetic storm activities (Ware, et al 2000). The climatic parameters will be estimated by measuring phase delays in GPS signals caused by the ionosphere and neutral atmosphere. These delays when measured to high precision and in combination with surface pressure data can be converted into Integrated Water Vapor (IWV) and Total Electron Content (TEC), along each GPS ray path (Bosy et al, 2011). The resulting continuous, accurate, all-weather and real-time GPS data will then be used in modeling and forecasting climate variability.

Currently there are Five (5) operating GNSS Continuously Operating Reference Stations in Ghana, built and maintained by the Survey and Mapping Division of the Ghana Lands Commission and a proposed base station to be hosted on KNUST Campus to serve as Master Control Station (MCS) for this assignment. The station will also contribute data to the Geodetic Reference Network of Ghana.

7. Methodologies

The study will be much of research work with some assisted tutorials from KNUST and partner faculty members in GNSS Signal Processing, Differential Equations (Ordinary & Partial), Fluid Dynamics and Climatic Modeling. In addition, a working visits to collaborative institutions to study current modeling, processing and data assimilation techniques and its adaptation to lower latitude regions. The overall methodology will be based on the strategies outlined in the TOUGH, 2006 final report. Data management, pre-processing and dissemination will be advanced based on strategies stated by Ware et al., 2000 in the SoumiNet paper. The general approach is enumerated below:

i. Study the Architecture, Operations and Maintenance of GNSS Base Station and configuring it to log all observables in view;
ii. Review reference manuals, manuscripts and software user guides associated with equipment, sensors for GNS S Meteorological and surface variable measurements;
iii. Visit the Met Offices in Ghana and study the NWP used there and source for archived data;
iv. Review already developed GCMs and test their adaptation for Local-scale used in lower latitude region such as Ghana;
v. Study Data Assimilation, Parameterization Schemes and Downscaling Techniques;
vi. Pre-process GNSS Observational logs to properly handle biases and complicated observation error correlations;
vii. Estimate Total Electron Content and Integrated Water Vapour from the Base Stations
viii. Measure Surface Variables
ix. Downscale GCMs for Localized adaptation
x. Test the developed model
xi. Write dissertation report.

Equipment and Data....

The research proposes to use these facilities and resources:

- ✓ Books, Journals and Catalogues on
- ✓ GNSS Signal Processing and Applications;
- ✓ CORS operation and maintenance;
- ✓ Data Assimilation, Parameterization Schemes and Statistical Downscaling
- ✓ Computer Codes, Scripts and Programs on Regional Climatic Models and General Circulation Models
- ✓ Barometric Pressure, Temperature and Humidity data from ground-based Sensors
- ✓ Geodetic-grade GNSS receiver, GPS antenna, Data logger and Accessories
- ✓ Field Measurements
- ✓ Matlab and C++ Programming Languages
- ✓ PCs equipped with internet connectivity.

8. Work plan

No.	Activity	Start	End	Year 1 (April '12 – March '13)											
				A	M	J	J	A	S	O	N	D	J	F	M
1	Synopsis Approval and Selection of Co-supervisor	00	03												
2	Synopsis Presentation to KNUST Faculty	03	03												
3	Study of Literature on GNSS Signals and Climate Modeling	00	12												
4	Visit Ghana Meteorological Offices	03	04												
5	Audit Course in Research Methodology	??	??												
6	Audit Course in Scientific Writing	??	??												
7	Audit Course in Climate Change Processes & Mitigation	??	??												
8	Audit Course in Fluid Dynamics	06	09												
9	Audit Course in Differential Equations	06	09												
10	Audit Course in Signal Processing	06	09												
11	Departmental Seminar	06	12												
12	GNSS Station Set-up	07	09												
13	Start Data Logging	10	12												
14	Write Technical Notes	03	12												

No.	Activity	Start	End	Year 2 (April '13 – March '14)											
				A	M	J	J	A	S	O	N	D	J	F	M
1	Proposed Stay Abroad	00	05												
2	Audit Course in Simulation Modeling in the Environmental Sciences	00	03												
3	Audit Course in Multivariate Data Analysis in Environmental Sciences	00	03												
4	Audit Course in Climate Modeling & Data Assimilation	00	05												
5	Assess General Circulation Models and Downscaling Techniques	00	05												
6	Departmental Seminar	06	12												
7	Estimation of TEC and IWV from GNSS Observational Logs	06	12												
8	Modeling of NWP and Downscale GCMs	06	12												
9	Write Technical Notes	06	12												

No.	Activity	Start	End	Year 3 (April '14 – March '15)											
				A	M	J	J	A	S	O	N	D	J	F	M
1	Proposed Stay Abroad	00	05												
2	Estimation of TEC and IWV from GNSS Observational Logs	00	05												
3	Modeling of NWP and Downscale GCMs	00	05												
4	Test Developed Models	00	10												
5	Departmental Seminar	06	12												
6	Compile Technical Notes and Write Draft Thesis	03	12												
7	Submit Draft Thesis	11	12												

9. References

Annamalai, H., Hamilton, K., and Sperber, K. R. 2007. The South Asian Summer Monsoon And Its Relationship With ENSO In The IPCC AR4 Simulations, J. Climate, 20, pp1071–1092, doi:10.1175/JCLI4035.1.

Bosy, J., Rohm, W., Sierny J. and Kaplon, J., 2011. GNSS Meteorology, International Journal on Marine Navigation and Safety of Sea Transportation, Volume 5 Number 1

CCSP, 2008: Climate Models: An Assessment of Strengths and Limitations. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Bader D.C., C. Covey, W.J. Gutowski Jr., I.M. Held, K.E. Kunkel, R.L. Miller, R.T. Tokmakian and M.H. Zhang (Authors)]. Department of Energy, Office of Biological and Environmental Research, Washington, D.C., USA.

Dobler, A. 2010. Downscaling of general circulation models in two alpine regions: The European Alps and the Himalayas. PhD Thesis. Johann Wolfgang Goethe-Universitat Frankfurt am Main

Dobler, A. and Ahrens, B. 2008. Precipitation By A Regional Climate Model And Bias Correction In Europe And South Asia, Meteor. Z., 17, pp499–509.

Gardner, L. 2007. Windows to the Universe, http://www.windows2universe.org/bio/lisa.html. Accessed on Feb, 2012.

McGuffie, K. and Henderson-Sellers, A. 2005. A Climate Modelling Primer, Third Edition. John Wiley & Sons, Ltd ISBN: 0-470-85750-1

Pipitone, J. 2010. Software Quality in Climate Modelling. MSc Thesis, Graduate Department of Computer Science, University of Toronto

Shackley, S., Young, P., Parkinson, S. and Wynne, B. 1998. Uncertainty, Complexity and Concepts Of Good Science In Climate Change Modelling: Are GCMs The Best Tools? Climatic Change, 38(2): pp159/205

Soos, A. 2010. Global Warming and Climate Models, Environmental News Network, web site http://oilprice.com/The-Environment/Global-Warming/Global-Warming-And-Climate-Models.html. Accessed on Feb, 2012

von Storch, H. 2005. Models of Global and Regional Climate. Encyclopedia of Hydrological Sciences. Edited by M G Anderson. John Wiley & Sons, Ltd.

TOUGH, 2006. Targeting Optimal Use of GPS Humidity Measurements in Meteorology, Section 6. Final Report. EVG1-CT-2002-00080. http://tough.dmi.dk

Ware, R. H., Fulker, D. W., Stein, S. A., Anderson, D. N., Avery, S. K., Clark, R. D., Droegemeier, K. K., Kuettner, J. P., Bernard Minster, J. and Sorooshian, S. 2000. SuomiNet: A Real-Time National GPS Network for Atmospheric Research and Education. American Meteorological Society Bulletin No. 81, pp 677-694.

Wikipedia, 2012. http://en.wikipedia.org/wiki/Main_Page.

10. Proposed PhD courses

i. Research Methodology
ii. Scientific Writing
iii. Climate Change Processes & Mitigation
iv. Fluid Dynamics
v. Differential Equations
vi. Signal Processing
vii. Simulation Modeling in the Environmental Sciences
viii. Multivariate Data Analysis in Environmental Sciences
ix. Climate Modeling & Data Assimilation

11. Time Schedule (courses, stays in Denmark/abroad/at other national institutions, publishing of results).

		Courses	Time
a.	1st Stay	▪ Audit Course in Simulation Modeling in the Environmental Sciences ▪ Audit Course in Multivariate Data Analysis in Environmental Sciences ▪ Audit Course in Climate Modeling & Data Assimilation ▪ Assess General Circulation Models and Downscaling Techniques	April 2013 to August 2013
b.	2nd Stay	▪ Estimation of TEC and IWV from GNSS Observational Logs ▪ Modeling of NWP and Downscale GCMs ▪ Test Developed Models	April 2014 to August 2014

12. Scientific competences that the student will get from the project

The Project will afford me the opportunity to:

- work with a multi-cultural faculty in using state-of-the-art ICT to conceive, design and complete an independent research work.
- acquire the needed statistical and modeling techniques in handling and analyzing large sample sizes
- improve upon my analytical thinking and reasoning in handling scientific projects
- be a member of the elite team of Researchers in Climate Assessment and Predictions.
- gain a higher academic degree that will be valued in all facets of our socio-economic sectors.

13. Date and signatures

	Date	Name	Signature
Principal Supervisor	**28-03-2012**	**Dr. –Ing Collins Fosu**	
Project Supervisor	**??**	**??**	