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Low Latitude Aeronomy Study in Africa

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UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

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Final Report

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14. ABSTRACT

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Final Report
Low Latitude Aeronomy Study in Africa

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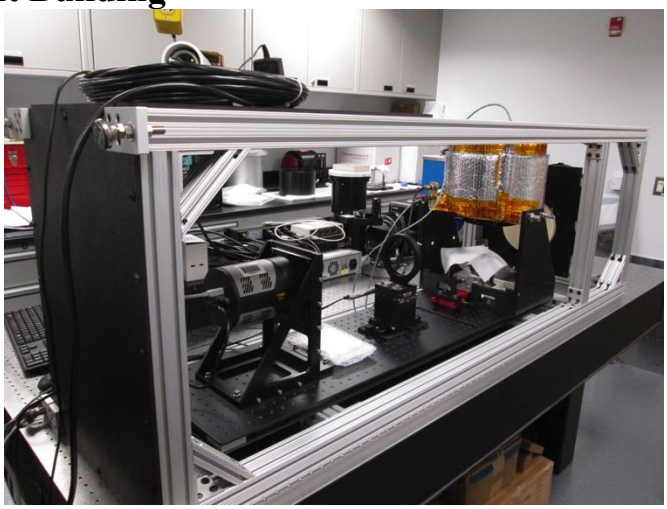
1. Project Overview

The main objective of this project is to study the longitudinal variations of the plasma bubble and its association with the thermospheric wind. To achieve this goal, we proposed to deploy a Fabry-Perot interferometer in the West African nation of Ivory Coast to measure thermospheric winds. The reason we want to go to Africa is because the plasma bubble occurrence is large in Africa and we do not understand why. Because the Rayleigh-Taylor instability is responsible for the plasma bubbles, we also plan to use the TIEGCM to calculate the Rayleigh-Taylor (R-T) instability to understand how the neutral wind affects the R-T growth rate. The new observations will help validate the simulation results from the TIEGCM.

2. Accomplishments

2.1 Instrument Building



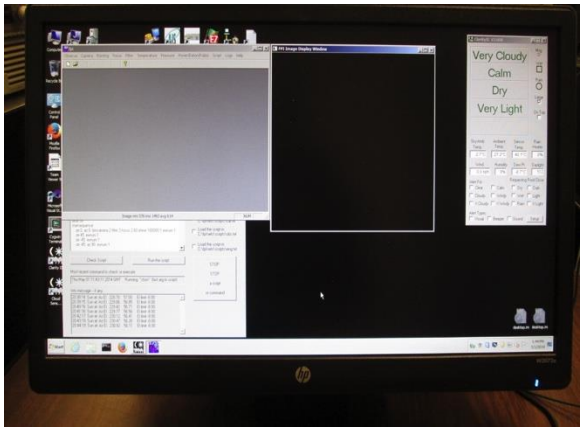


Figure 1. The instrument undergoing endurance test in the lab (top), FPI computer electronics (bottom left) and user interface (bottom right).

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During the first year of the project, the major effort was on instrument building. The task was successfully completed (Figure 1). The instrument completed endurance test in the lab and was packed and ready for shipment.

2.2 Instrument Deployment Preparation in Ivory Coast

NCAR also worked closely with our Ivory Coast colleagues to make the necessary preparation for the site. An optical dome was acquired and an aluminum base plate was attached to the optical dome for mounting on the top of the house for the instrument. The dome was also packed and ready for shipping. NCAR also obtained an export license for instrument to be shipped to Ivory Coast. Our Ivory Coast colleagues constructed a new hut to house the FPI with their funding (Figure 2).

Figure 2. The hut (under construction earlier in 2015) in Korhogo Ivory Coast for housing the FPI. The hut should be ready by now.

2.3 Deployment of small FPI

During the first year, we have finished building of the instrument, which was packed in crates and ready for shipping. However, the instrument stayed at NCAR, because of an unexpected hurdle in shipping the instrument to Ivory Coast. The Ivory Coast custom requires substantial import duty for the instrument. Our Ivory Coast colleagues had anticipated that the import duty would be waived. Consequently, the deployment in Ivory Coast was not realized.

However, in order to provide much needed observations in Africa, we built a small FPI for the redline nightglow (630nm) thermospheric wind observation only. The large FPI built for Ivory Coast cannot be deployed easily without dedicated local

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facility. As a result, we could not just deploy the large FPI to other locations. A small FPI, on the other hand, is more flexible and allows more deployment options. In our first attempt, we went to Cape Verde Atmospheric Observatory, which is a British and German joint atmospheric research facility. The facility has reliable power and internet link. The project PI went to Cape Verde and deployed the instrument at the observatory (Figure 3). However, because the site is on the coast and the environment is very humid. It is not good for long-term optical instrument with the enclosure we built. After careful consideration, we decide to take the instrument back to NCAR.

Figure 3. The small FPI (left) and Cape Verde Atmospheric Observatory (right). The FPI was on the small tower on the left.

We presented preliminary results from Cape Verde during the International Symposium on Equatorial Aeronomy in Bahir Dar, Ethiopia in 2015. We compared Cape Verde observations with that from Arecibo, which is at the same geographic latitude as Cape Verde but higher geomagnetic latitude. We had anticipated some differences in the thermospheric winds because Cape Verde is under the Equatorial Ionosphere Anomaly (EIA), where the ion drag should be greater leading to smaller neutral winds. However, we did not find any significant differences in the zonal winds between the two locations (Figure 4) under clear sky (later half of the night). A further simulation with the TIEGCM will be conducted to examine the effect of the ion drag in the EIA. This is the first time an FPI making thermospheric winds observation off the coast of the Africa. The results are intriguing. It is regret that we do not have a longer data set. We hope that we will have the opportunity to deploy an instrument in Cape Verde for long term observations in the future. Cape Verde observations can help bridge the gap between the African and American sectors.

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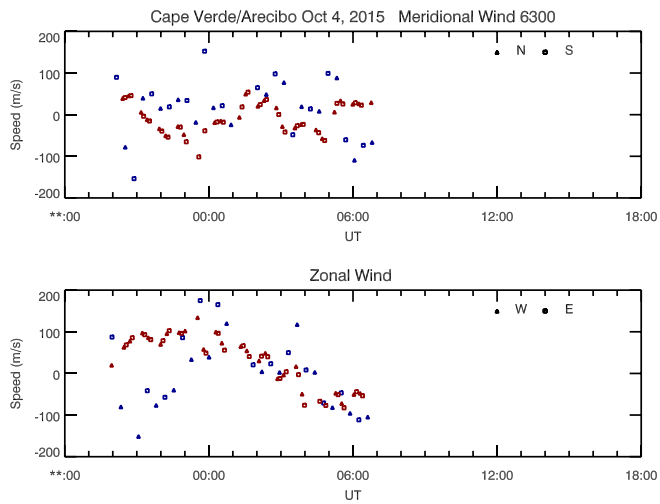

Figure 4. The Thermospheric winds comparison between Cape Verde (blue) and Arecibo (red). The Arecibo data are shifted by 3 hours so the two data sets are in the same local times. The early part of the Cape Verde data may be affected by cloudy weather.

For the second deployment attempt, we selected Abuja, Nigeria. Our Nigerian colleagues were very supportive and they have a building dedicated to the optical instruments. Prof. Shiokawa of Nagoya University has already deployed an all sky camera in the same building. The PI went to Abuja and deployed the instrument with strong support from the Nigeria Space Research and Development Agency. The instrument was deployed and operational. Because of the delay, the instrument deployment came near the end of the project. We do not have much time to analyze the new observational results from Abuja (Figure 5).

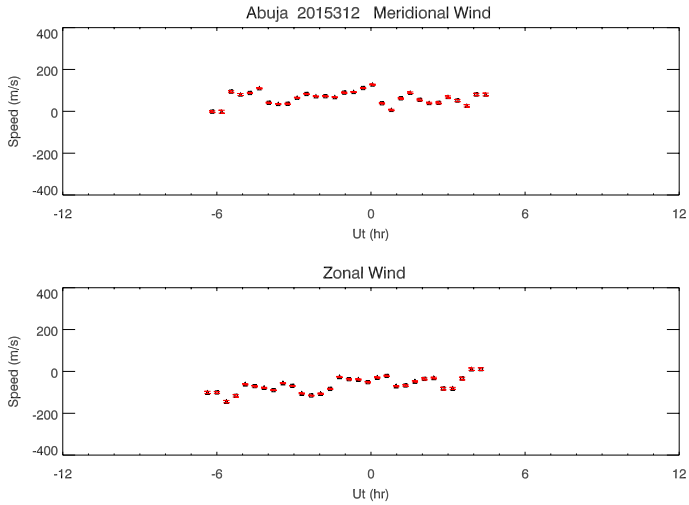

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Figure 5. Preliminary thermospheric wind data from Abuja (top). The small FPI in Abuja (bottom left) and observatory in Abuja (bottom right).

We have not given up the deployment at Ivory Coast. Only recently (late January 2016), our Ivory Coast colleague Prof. Vafi Doumbia has found a solution to the import duty problem. Unfortunately, after the two Africa deployment trips, we cannot deploy the large FPI to Ivory Coast under this research grant without additional funding. We will write another proposal to AFOSR to continue this effort of deploying instruments in Africa to study low latitude aeronomy in Africa and support other investigators with new observational results. The instrument is ready for shipment and deployment.

2.4 Model Simulations

While the instrument deployment was delayed, we have started model simulations for the Rayleigh-Taylor (R-T) instability growth rate using the NCAR TIEGCM, which is part of our proposed research effort. The R-T instability is responsible for the plasma bubble. The simulated R-T growth rate distribution resembles the distribution of the occurrence of the bubble. A JGR paper was published on the influence of the nonmigrating tide on the R-T growth rate. We found that nonmigrating tide has a significant influence on the R-T growth rate particularly during solar minimum. The effect of the diurnal eastward propagating zonal wave number 3 (DE3) nonmigrating tide effect is very apparent in the simulation results (Figure 6). The effect of the DE3 on the R-T growth rate is closely connected the thermospheric zonal wind, which is modulated by the DE3. Thermospheric zonal wind can change the vertical ion drift, which can alter the R-T growth rate [*Wu*, 2015].

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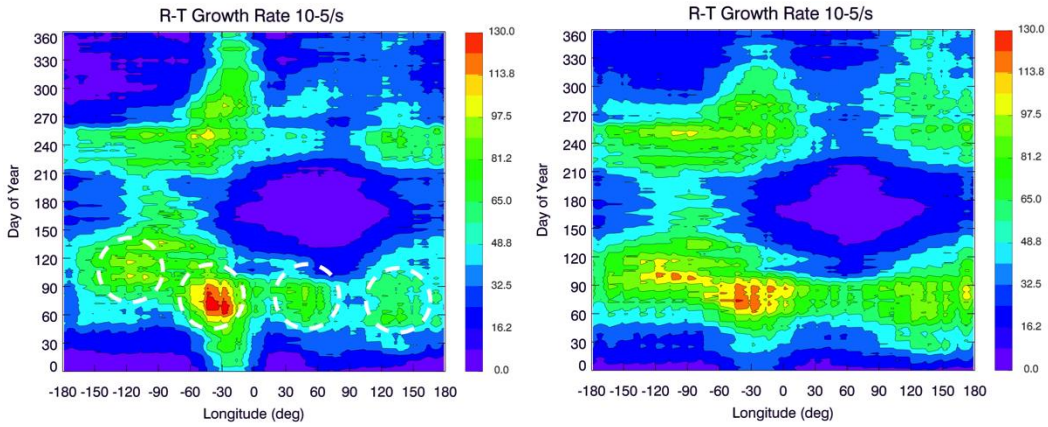

Figure 6. R-T growth rate with nonmigrating tide effect (left) and without (right) [*Wu*, 2015]. The DE3 features are highlighted with white dashed-line cycles.

We also investigated the solar influence on the R-T growth rate. The TIEGCM simulations of R-T growth rate for solar minimum and maximum are consistent with observed bubble occurrences under the respective solar conditions (Figure 7). Similarly to influence of the nonmigrating tides, the solar effect is also closely connected with the thermospheric zonal winds. During solar maximum, the zonal winds are greatly enhanced due to strong solar heating in the thermosphere. Consequently, the vertical ion drift was also increased through dynamo effect. In turn, the R-T growth rate also elevated. We just submitted a paper to JGR related to the solar effect on the R-T growth rate [*Wu*, 2016].

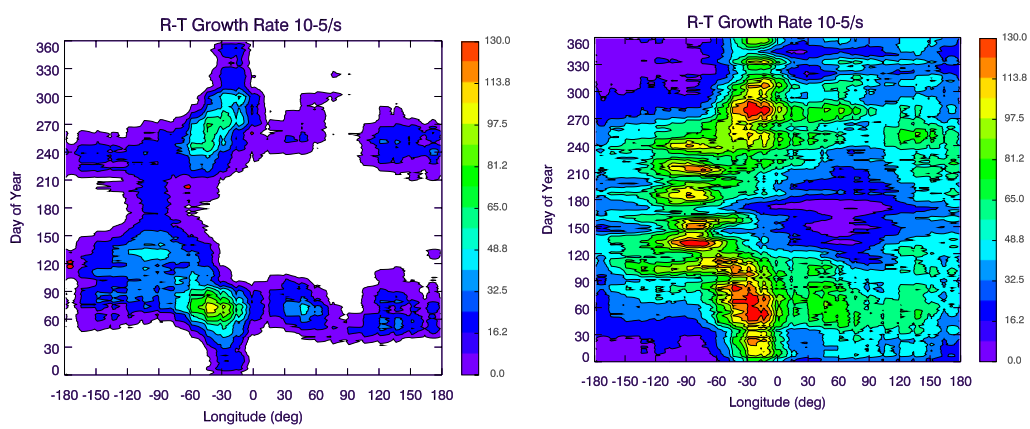

Figure 7. R-T growth rate during solar minimum (left) and maximum (right) [*Wu*, 2016].

While the TIEGCM simulations give largely consistent results, there are still discrepancies between the simulated R-T growth rate and plasma bubble occurrence distributions. The issues in the TIEGCM can only be mitigated through validation with observations. Since the thermospheric winds are the key of the R-T growth rate, thermospheric wind observations are very important for future improvement of the

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TIEGCM and the development of forecast capability of the plasma bubbles. The FPI observations in Africa will play an important role in the future.

3. Summary

We have successfully completed the instrument construction. The unexpected issue with Ivory Coast import duty has prevented us from deploying the FPI in Ivory Coast as originally planned. However, by improvising we were able to construct a small FPI and have it deployed in Abuja, Nigeria and obtained thermospheric winds in West Africa for the first time.

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Overall, the project is a very good start for both modeling and observational efforts on equatorial aeronomy study in Africa. During a recent International Symposium on Equatorial Aeronomy in Ethiopia, we met many colleagues from Africa, who are greatly interested in the new observational results from Africa. We are looking forward to more collaboration in the future.

Publications

Wu, Q., J. Noto, R. Kerr, S. Kapali, J. Riccobono, W. Wang, and E. R. Talaat (2014), First Palmer and Millstone Hill midlatitude conjugate observation of thermospheric winds, *J. Geophys. Res. Space Physics,119*, doi:10.1002/2013JA019062.

Deng, Y., Y. Huang, Q. Wu, J. Noto, D. Drob, and R. B. Kerr (2014), Comparison of the neutral wind seasonal variation from midlatitude conjugate observations, *J. Geophys. Res. Space Physics, 119,* doi:10.1002/2013JA019716.

Wu, Q. (2015), Longitudinal and seasonal variation of the equatorial flux tube integrated Rayleigh-Taylor instability growth rate, J. Geophys. Res. Space Physics, 120, 7952–7957, doi:10.1002/2015JA021553.

Wu, Q., (2016), Solar Effect on the Rayleigh-Taylor instability growth rate as simulated by the NCAR TIEGCM, J. Geophys. Res., Space Physics, under review.

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Presentations

1. Wu, Q., Vafi Doumbia, A new Fabry-Perot interferometer for Korhogo, Cote d'Ivoire (9.33N, 5.43W), CEDAR workshop, Boulder, Co June, 2013.
2. Emery, B. A. Preeti Bhaneja, Dieter Bilitza; Jorge L. Chau; William R. Coley; Douglas P. Drob; Tzu-Wei Fang; Bela G. Fejer; Benjamin T. Foster; Kathrin Haeusler; McArthur Jones; Jeffrey Klenzing; Hermann Luhr; John M. Retterer; Arthur D. Richmond; Patrick A. Roddy; Russell Stoneback; Yi-Jiun Su; Qian Wu; Xiaoli Zhang, Matching CHAMP and C/NOFS Climatology at Low Latitudes with the ionosphere-thermosphere TIEGCM and the plasmasphere GIP Models, AGU Meeting of the Americas, Cancun, May 2013.
3. Yamazaki, Y., A. D. Richmond, A. Maute, Q. Wu, Geomagnetic solar-quiet (Sq) variation: NCAR model vs. Ground magnetometer observations for Nov 2009, IAGA, 2013.
4. Wu, Qian, Thermospheric wind observations and simulations, SCOSTEP's 13th Quadrennial Solar-Terrestrial physics symposium, Xian, Oct 12, 2014.
5. Wu Qian, Thermospheric wind observation and space weather research at NCAR, Space Weather Workshop, Boulder, Co April 15, 2015.
6. Wu, Qian, J. Noto, Vafi Doumbia, Babatunde Radiu, Study longitudinal variations of the equatorial spread F occurrence by modeling and observations, 14th International Symposium on Equatorial Aeronomy, Bahir Dar, Ethiopia, Oct 19, 2015.

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