

Final Report for Partners Project S05-52249

Project Title: Characteristics of Trade-wind Inversion over the Hawaiian Islands

University: University of Hawaii

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Section 1: Summary of Project Objectives

The trade-wind inversion over the Pacific is one of the primary factors in regulating convective activity over the Hawaiian Islands. Despite the fact that a trade-wind inversion is present much of the time, very little research has been conducted regarding variations of this feature. Operational forecasters at the National Weather Service (NWS) Weather forecast Office (WFO) Honolulu do recognize that when the trade-wind inversion is higher or absent, trade-wind rainfall tends to be higher. However, without in-depth climatic statistics for the trade-wind inversion, for a given trade-wind day, forecasters do not have a clear view on how the observed trade-wind inversion characteristics deviate from the long-term mean at the same time of the year and how that would relate to rainfall across Hawaii. The results from this study would provide valuable information for developing climate based guidance for Quantitative precipitation forecasting (QPF) from the observed trade-wind inversion characteristics for a given day.

In this project we would like to provide climate statistics of the trade-wind inversion over an annual cycle as well during anomalous climatic conditions (e.g., El Nino), which have a strong influence on Hawaiian weather. Twice daily soundings from Hilo, Hawaii and Lihue, Kauai will be used for the compilation of trade-wind inversion statistics at both sites.

Section 2: Project Accomplishments/Findings

Five years (1999-2004) of rawinsonde observations, launched at 0000 and 1200 UTC from Hilo and Lihue, were analyzed to develop median statistics for Trade-wind inversion (TWI) base height, TWI frequency, and strength and thickness of the stable layer. Rawinsondes launched under disturbed conditions (upper level troughs/lows, cold fronts, and convection due to mesoscale trade-wind disturbances) associated with the trade wind regime were excluded. The results of this study will provide forecasters and researchers a baseline as to what is considered “normal” for TWI attributes over Hawaii. These characteristics are important for forecasting rainfall, sky conditions and airflow around the islands under a typical trade-wind regime.

Throughout the year, the TWI base has a range of 400 m with two maxima (September-

October and April) and two minima (January and June). The mechanism for a higher TWI base in the fall and spring months is most likely due to the transient nature of the Subtropical high (STH) as it moves from its summer to winter position. The frequency of the TWI is lowest ($\approx 35\%$) during January, as mid-latitude storms to the north affect the islands, but is present 75-80% of the time from May to September. The strength and thickness also show seasonal variations ranging from 3.5^0 to 6^0 and 300 m to 670 m, respectively. The strength of the TWI has an annual maximum in June when the STH center is farthest, a minimum in spring and a secondary minimum in fall. The thickness of the TWI stable layer also has a similar seasonal trend.

A comparison between Hilo and Lihue TWI statistics was made. Strength and thickness of the TWI stable layer were not significantly different between the two locations. The presence of the TWI was slightly more frequent at Hilo during winter months because few frontal passages reach far enough south to affect the Big Island. The most notable difference was that the base height is higher at Hilo by 200 m year round because of the influences from the Big Island's extreme terrain.

Migratory highs that bring E-NE winds behind the winter cold fronts (or shear lines) to the islands can cause an inversion similar to the TWI from the subtropical high (STH). In winter, the STH ridge is closest to the islands. Migratory highs track farthest south as they follow mid-latitude storms. Ridges and subsidence regions of these migratory highs also cause a suppression of the inversion. Migratory highs occur during September and May. They are most common between October and April with a maximum frequency about 12-15% in winter months.

The data analyzed included a moderate El Nino year. During the summer months, the subtropical high is weaker during El Nino with weaker trades and slightly lower trade-wind frequencies. During the winter months, the TWI statistics between El Nino and other years are similar except the trade-wind frequencies are significantly lower than other years. In the El Nino January at Lihue, trades were almost absent because the ridge axis of the subtropical high was pushed south of Lihue.

During this 5-year period, 2001-02 is the wettest winter at Hilo with a rainfall total of 58.91 in during December-February. The driest winter in this period at Hilo occurred during the moderate El Nino winter of 2002-03 with a rainfall total of 17.13 in. For the most recent strong El Nino event during 1997-1998, the winter rainfall total at Hilo is 10.63 in. The winter drought at Hilo during both El Nino events is attributed to fewer winter storms for both years with much less rainfall during non-trade-wind days. There are no significant differences in trade-wind rainfall and trade-wind inversion base statistics between El Nino winters and other winters at Hilo, except during El Nino winters trade-wind frequencies were lower.

Related Accomplishments

The University, NCEP and NWS continued research collaboration on the studies of heavy rainfall, high wind and trade-wind weather over the Hawaiian Islands as part of the PhD

requirements for Mr. Y. Zhang. We have summarized the results for publication in Weather and Forecasting. The University continues to run experimental forecasts using NCEP Mesoscale Spectral Model/Land Surface Model (MSM/LSM) (<http://www.soest.hawaii.edu/MET/Faculty/rsm/index.html>) and MM5/LSM (<http://www.soest.hawaii.edu/MET/Faculty/mm5/index.html>) for the Hawaiian Islands and the Fiji Islands (<http://www.soest.hawaii.edu/MET/Faculty/mm5/FIJI.html>).

Section 3: Benefits and Lessons Learned: Operational Partner Perspective

Rainfall across the Hawaiian Islands is one of the most challenging forecast problems, and produces the most impact of all sensible weather elements to the residents and visitors to the state. The results of this project will be incorporated into day-to-day forecasting operations at the Honolulu Weather Forecast Office (WFO) with the goal of improving forecasts. This will be accomplished by development of a series of interactive procedures, called smart tools, for use within the Graphical Forecast Editor (GFE) software. WFO forecasters will run these smart tools, and using the resulting GUI will be able to modify various weather element grids, such as probability of precipitation and the quantitative precipitation forecast (QPF). The smart tools will provide powerful flexibility for the forecaster. For example, the forecaster could allow the smart tool to automatically determine forecast inversion heights and strengths from model data, and then using logic based upon the results of this work, the tool would automatically modify model rainfall or climatology data and populate the applicable weather element forecast grid. Currently a smart tool to produce QPF grids is under development. Logic relating to the forecasted TWI height versus climatology will be added and tested. It is anticipated that WFO Honolulu will begin operationally producing QPF grids by November 2006.

Using GFE software to create the forecasts allows the WFO forecaster to run simple procedures to modified other weather elements and ensure consistency between them. Therefore having improved gridded rainfall forecasts will also lead to improved cloud cover forecasts since the majority of rain falls from low level cumuli and non-precipitating mid and high level cloudiness is quite rare. Improved cloud cover and rainfall forecasts will in turn lead to improved temperature and humidity forecasts.

Section 4: Benefits and Lessons Learned: University Partner Perspective

The primary benefit to the university was the exposure of our students to operational forecasting and better understanding of forecast problems. Also, the project provides the opportunity to interact with NWS staff and to conduct research related to problems that are important to operational forecasting. This research also fulfilled part of B. Bingaman's MS degree requirements.

Section 5: Publications and Presentations:

Publications:

Bingaman, J. B., 2005: Characteristics of the trade-wind inversion over Hawaii, MS Thesis,

Dept. of Meteorology, UH, 79pp.

Related Publications:

- Zhang, Y., Y.-L. Chen, S.-Y. Hong, H.-M. H. Juang and K. Kodama, 2005: Validation of the coupled NCEP Mesoscale Spectral Model and an advanced Land Surface Model over the Hawaiian Islands: Part I: Summer trade-wind conditions over Oahu and heavy rainfall events. *Wea. Forecasting*, **20**, 847-872.
- Zhang, Y., Y.-L. Chen, and K. Kodama, 2005: Validation of the coupled NCEP Mesoscale Spectral Model and an advanced Land Surface Model over the Hawaiian Islands. Part II: A high wind event. *Wea. Forecasting*, **20**, 873-895.
- Zhang, Y., Y.-L. Chen, T. A. Schroeder, and K. Kodama, 2005: Numerical simulations of sea breeze circulations over northwest Hawaii. *Wea. Forecasting.*, **20**, 827-846..
- Juang, H.-M. H., C.-T. Lee, Y. Zhang, M.-C. Wu, Y.-L. Chen, K. Kodama, and S.-C. Chen, 2005: Applying horizontal diffusion on pressure surface to mesoscale models on terrain-following coordinates. *Mon. Wea. Rev.*, **133**, 1384-1402.

Related Presentations:

Chen, Y.-L. Y. Zhang, S.-Y. Hong, K. Kodama, H.-M. H Juang: Application of the NCEP Regional Spectral Model to improve weather forecasting in Hawaii. The 2nd AOGS Annual Meeting, June 20 - 24, 2005, Singapore.

Section 6: Summary of University/Operational Partner Interactions and Roles

B. Bingaman gave an informal presentation of her preliminary results to the forecasters during the grant period.