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PI: David P. Rogers

THE EFFECT OF THE STRUCTURE OF THE COASTAL MARINE BOUNDARY-LAYER ON THE DETECTION OF SHIP TRACKS

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LONG-TERM GOALS

The goal of this research was to understand the mean cloud-topped boundary layer conditions that favor the persistence of cloud lines associated with ship tracks.

SCIENTIFIC OBJECTIVES

The specific objectives of this work were to determine how the diurnal variability of the boundary layer affects the persistence of these tracks; to determine how variations in boundary layer structure associated with various coastal phenomenon affect the development and persistence of ship tracks; and to what extent the variations in ship track scales observed in satellite images can be tied to variations in coherent scales in the boundary layer.

APPROACH

Aircraft data collected during the Monterey Area Ship-Tracks (MAST) experiment, combined with similar data from the Atlantic Stratocumulus Transformation Experiment (ASTEX) was used to characterize the mean and turbulent structure of the boundary layer that favors the development of shiptracks. In particular aircraft patterns can be used to determine the boundary layer scales that appear to be critical to the size and distribution of the ship cloud lines. We are also using these data to look at the slope of the boundary layer to determine if the ship cloud requires the boundary layer to lift in a similar manner to the wakes observed from islands.

TASKS COMPLETED

We have completed the analysis of the aircraft data collected during MAST

SCIENTIFIC RESULTS

Large scale horizontal rolls can have a significant influence on turbulent transport across the atmospheric boundary layer; the formation and maintenance of such rolls is dependent on the thermal and dynamic stability of the boundary layer. We have aircraft observations of boundary layers, both with and without roll circulations, off the coast of California. The contribution of the rolls to the turbulent fluxes of heat, moisture, and momentum, and the variances of the three velocity components are determined for four cases. The fractional roll contributions to the u and w variances, and the sensible heat and along-wind momentum fluxes show a near linear increase with altitude, from less than 10% at 30 m to more than 70% at the top of the BL. The variance in v and cross-wind momentum flux are more scattered, although the variance shows a slight increase with altitude from about 40 to 60%. The latent heat flux also shows a great deal of scatter, especially in the lower third of the BL where the total flux is small; above this values range between about 40% and 85% but show no clear trends. A stability parameter, in the form of a bulk Richardson number is calculated for each of thirteen profiles through the boundary layer; it is found that the Richardson number successfully identifies those cases where rolls are present, and its exact value corresponds to some extent with the strength of the rolls. Values close to zero correspond to cases with well defined rolls; for $0.1 < Ri < 0.25$ rolls are found to exist, but they tend to be weak and patchy; no rolls are found where Ri is greater than the critical value of 0.25. Reynolds numbers are calculated from a number of different definitions, and indicate the dynamic instability of the shear dominated boundary layers.

IMPACTS

The results indicate that the longevity of ship tracks may be linked to the organization of the marine layer. Rolls produce regions of convergence that favor the formation and maintenance of clouds. A nearly saturated boundary layer is need for ship track formation. Thus the presence or absence of rolls may significantly affect the formation and detection of ship tracks.

TRANSITIONS

The results from this study have been made available to NRL Monterey to test and evaluate large eddy simulation models of the marine boundary layer.

RELATIONSHIPS TO OTHER PROJECTS

This work has led directly to the coastal waves experiment, which took place in June 1996. This project combined airborne lidar and in situ turbulence measurements to further explore the structure of the marine atmosphere. In addition techniques developed for this project have been applied to other programs, such as SHAREM 115.

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PUBLICATIONS

P - Brooks, I. M., D. P. Rogers, and J. W. Glendening, 1996: Boundary layer rolls and cloud bands: Aircraft observations and modelling results. 12th International Conference on Clouds and Precipitation, Zurich, Switzerland, September 19-23, 1996.

C - I. M. Brooks, D. P. Rogers, and D. W. Johnson, 1994: Modification of the marine boundary-layer and the development and evolution of shiptracks. Proceedings of the Fall Meeting of the AGU, EOS, 75, 44, 138. Oral Presentation

C - I. M. Brooks, D. P. Rogers, and D. W. Johnson, 1996: Observations of the Turbulence Structure of the Coastal Marine Atmospheric Boundary Layer. AMS conference on Meteorology and Oceanography of the coastal zone, January 1996. Oral Presentation

C - G. B. Raga, S. T. Siems, and I. M. Brooks, 1995 A Large Eddy Simulation of a nocturnal stratocumulus case observed during ASTEX. Proceedings of AMS Cloud Physics Conference, Dallas, 160-161, January 1995. Oral Presentation

P - Rogers, D.P., 1995: Coastal Meteorology. Reviews of Geophysics, Supplement, pp. 889-895, U.S. National Report to International Union of Geodesy and Geophysics 1991-1994.

P - Rotunno, R. and others, 1996: Coastal Meteorology and Oceanography; Report of the third prospectus development team of the US Weather Research Program to NOAA and NSF. *Bull. Amer. Meteorol. Soc.*, 77, 1578-1585.

P - Brooks, I. M. And D. P. Rogers, 1996: Aircraft observations of boundary layer rolls of the coast of California. *J. Atmos. Sci.*, accepted for publication.

PS - Johnson, D.W., G. M. Martin, I. M. Brooks, D. P. Rogers and C. A. Friehe, 1994: Aircraft observations of the evolution from stratocumulus to trade wind cumulus during ASTEX. *J. Atmos. Sci.,* submitted for publication.

C - Brooks, I. M. and D P Rogers, 1996: Turbulence in the Marine Atmospheric Boundary Layer: Aircraft Measurements and Lidar Visualization. *EOS*, 76, Supplement.

C - Rogers, D. P., L. V. M. Ström, and I. M. Brooks, 1996: Aerosol Variability and Cloud Development in the Stable Coastal Boundary Layer. *EOS*, 76, Supplement.

C - L. V. M. Ström, L. V. M, D. P. Rogers, and C. E. Dorman, 1996: Topographic Forcing of the Atmospheric Boundary Layer During CW96. *EOS*, 76, Supplement.

GRADUATE STUDENTS, POST DOCS

Graduate Students - 4 (2 female), two completed Ph.D. in 1996

Post-Doctoral Researchers - 2

PATENTS

none

PRESENTATIONS

Rogers, D.P., Coastal Meteorology - The State of the Science. Presented at the NRC Navy Strike Warfare and Ship-Self Defense Meeting, Fallon, Nevada, September, 1995.

Rogers, D. P., Marine Boundary Layer Processes: The role of air-sea interaction, surface exchanges and boundary layer development in the global climate. Presented at Jet Propulsion Laboratory/ Caltech. Summer School, August 1996.

Also, see publication list for conference abstracts and proceedings.

COMMITTEES AND PANELS

Coastal Ocean Processes Steering Committee (National Science Foundation)

American Meteorological Society Committee on Coastal Meteorology

American Meteorological Society Committee on Air-Sea Interaction

Symposium on Meteorology and Oceanography Support for Strike Warfare and Ship Self-Defense, Fallon, Nevada, September 11-14, 1995.

US Weather Research Program Prospectus Development Team #3, Wrightsville Beach, North Carolina, September 19-21, 1995.

US Weather Research Program Prospectus Development Team #7,The importance and mix of observations over the Pacific Ocean. Scripps Institution of Oceanography, La Jolla, California, July 17-19,1996.