Technical Progress Report

on

**Shipboard Measurements of the Cloud-Capped
Marine Boundary Layer During FIRE/ASTEX**

(For the Period 2/7/92-9/16/92)

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1. Introduction

ASTEX is a large multi-agency program to investigate all aspects of marine stratus clouds because of their overall importance in regulating the earth's climate system. During the month of June, 1992, the ASTEX field program focussed on clouds in the Eastern Atlantic because of the expected frequency of low clouds in that area. The experiment was based on the islands of Santa Maria in the Azores and Porto Santo about 800 km away in the Madeira Archipelago with large contingents of remote sensors operated from both islands. To form an equilateral triangle of remote sensors, a ship was used as the third platform.

The intent of our original proposal to DOE was to operate a set of remote sensors on a ship that could be functionally equivalent to a prototype CART system during ASTEX. Experience with modern remote sensors operating on such a platform would be valuable in making decisions about shipboard versus island deployment of CART remote sensors, and it would provide information useful in the selection of remote sensors for a maritime CART. Many of the ASTEX research goals are parallel to those of the DOE/ARM program and the work performed under this proposal will serve both.

The ship originally identified for the task was the R/V Akademik Kurchatov, a large research vessel operated by the former Soviet Union. Instability in the former Soviet Union prior to the ASTEX field program made it impossible for the Kurchatov to participate, and as a result, a reduced set of instruments was deployed on the smaller NOAA research vessel the R/V Malcolm Baldrige. In addition to supporting remote sensors on the R/V Baldrige, this DOE grant made it possible for full participation of WPL remote sensors on Porto Santo.

2. Project Statement of Work

During the period from 2/7/92 through 9/16/92 a large suite of remote sensors was prepared and deployed on the R/V Baldrige and on Porto Santo Island; most of the effort was related to the field program although some analyses have already started. WPL instruments on the Baldrige included a complete suite of surface flux sensors (sonic anemometer-thermometer, fast hygrometer, and solar and IR flux radiometers), a 2-channel microwave radiometer, a 10.6 μm IR radiometer, a 915 MHz Doppler wind profiler, a lidar ceilometer, and an Omega rawinsonde system. A wide variety of atmospheric chemical and aerosol measurements were made by other investigators.

On Porto Santo the WPL instruments included an 8 mm wavelength Doppler cloud-sensing radar, a scanning CO_2 Doppler lidar, a three-channel microwave radiometer, a 10.6 μm IR radiometer, a pyranometer, and a pyrgeometer. In brief, the work performed during this period was the following: 1) preparing the instruments for operation on the ship and the island and shipping

them to their final destinations, 2) setting up, checking out and operating the instruments during the four week data collection period of ASTEX, 3) returning the instruments to Boulder, CO, and 4) starting the analysis of the comprehensive data sets collected during ASTEX.

The Malcolm Baldrige departed Miami on the evening on May 30. The remote sensing systems were operated continuously from June 1 to June 28 (the microwave radiometer operation continued until it was unloaded at Porto Santo on July 5), although there was a hardware problem with one of the oblique beams on the wind profiler that was not repaired until June 11. Following the usual shakedown period for a new ship installation, the shipboard flux system operated continuously from June 6 to June 28, with several shutdown periods associated with port calls (June 10 and June 16) or running down wind. Rawinsondes were launched at 3 hour intervals beginning on June 4. The dataset contains a wide variety of conditions including several days of very light winds, stratocumulus clouds, and scattered clouds. Light precipitation at the surface was observed on a few days influenced by frontal passages. In the middle of the experiment a change in the synoptic pattern brought extremely polluted air into the region from the European continent. This provided a nice contrast to the very clean conditions that prevailed up to that time. Aircraft flybys occurred on three days; on June 16 six hours were devoted to detailed flux and mean meteorological comparisons with both the NCAR Electra and the British C-130. A preliminary check with the NCAR results showed excellent agreement. The ship also devoted one day to an in-situ comparison with the Woods Hole Oceanographic Institution meteorological buoy deployed in the center of the ASTEX triangle.

On Porto Santo Island, a new high pulse rate CO₂ Doppler lidar with much improved velocity resolution was operated for the first time. The instrument provided wind measurements in the clear air and into the lower portions of marine boundary layer (MBL) clouds. Initial assessment of measurement capability, based on returns from solid targets, indicates a velocity measurement accuracy of better than 10 cm/s.

The 8 mm wavelength Doppler radar operated nearly continuously for the four week period, and it collected a rich data set on the microphysical and dynamical structure of MBL clouds. Initial analysis of the data has revealed long lasting "microcells" which are less than 2 km deep and have a large cloud mass associated with a rather small cloud generation core. We have started to couple radar data with a one-dimensional cloud model to produce profiles of drop size distributions and liquid water content in MBL clouds. Turbulence profiles and vertical velocity statistics are being compiled within the MBL clouds. Radar and lidar measurements of vertical velocity statistics and turbulence properties for both the clear, partially cloudy, and cloud-topped marine boundary layers will yield information on the relative effects of cloud top cooling and surface heating under the

different cloud conditions. The radar collected several high quality data sets in cirrus clouds, an unanticipated spin-off from the MBL measurement program. The radiometer systems also operated continuously for four weeks and will allow us to produce time series and statistical analyses of integrated liquid water and integrated water vapor over the island.

3. Project Plan for the Remaining Period

The data analysis for the remaining weeks of FY-92 will continue along the lines suggested above. No major changes in the direction of our analysis effort are anticipated during this short period.

4. Plan for FY-93

During FY-93 we plan to investigate the ability of Doppler radar coupled with a one-dimensional cloud model to profile microphysical parameters in MBL clouds. A large assortment of clouds, especially those with drizzle, will be examined in this way to estimate liquid water profiles, liquid water flux profiles, and condensation and evaporation rates. Comparisons will be made with radiometer retrievals of integrated liquid in the cloud wherever possible. We will begin to compile statistics of vertical velocities, specifically the profiles of second and third moments of vertical velocity fluctuations in clouds with the radar and below cloud base with the lidar. Fluxes of momentum and turbulent kinetic energy will be computed with both the radar and lidar. The preliminary discovery of long-lasting microcells in the MBL will be validated with an examination of the large data set collected by the scanning Doppler radar during ASTEX; characteristic sizes, frequencies of occurrence, lifetimes and other features of these cells will be documented. Ice particle characteristic size and concentrations in cirrus clouds will be estimated from the combined radar and IR radiometer data set.

The shipboard data analysis efforts will follow the lines developed for the previous deployment of this system. A cleaned-up version of 1-hourly averaged fluxes and surface meteorology will be produced and distributed to interested parties. The lidar ceilometer data will be processed to produce hourly estimates of cloud fraction and cloud base height. The wind profiler consensus profiles and the rawinsonde data will be quality controlled and distributed. The wind profiler signal-to-noise data will be processed to identify the height of the persistent inversion and, in combination with the ceilometer, the cloud thickness. The solar radiative fluxes will be processed to produce estimates of cloud albedo and liquid water for comparison with the microwave radiometer. All hourly processed databases will be integrated for collaboration with satellite sensing groups at WPL and NASA Langley.

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