Upgraded Doppler Rayleigh Lidar and Comparisons with Stratospheric Radar: 1: Observations Following Initial System Modifications

P. A. Castleberg[1,2], J. S. Friedman[1], J. Y. N. Cho[1], C. A. Tepley[1], and M. C. Kelley[2]

[1] Arecibo Observatory, Cornell University, P. O. Box 995, Arecibo, Puerto Rico 00613, U.S.A.
Ph. (809) 878-2612, FAX 809 878-1861, E-mail: pcastle(jonathan, jcho, and craig)@naic.edu

[2] Cornell University, School of Electrical Engineering, Ithaca, New York 14853, U.S.A.
Ph. (607) 255-4844, FAX 607 255-6236, E-mail mikek@ee.cornell.edu

We present lidar observations of density fluctuations in the presence of thin cloud and aerosol layers with complementary stratosphere/troposphere (ST) radar wind profiles. These observations followed the initial stage of a Doppler Rayleigh lidar system upgrade. These initial observations were made during the week of September 9 -18, 1994, coincident with the Space Shuttle Lidar In-Space Technology Experiment (LITE).

The experimental goals of the September 1994 run were twofold. The first goal was the characterization of the Doppler lidar wind profiling mode following the initial modifications, and prior to subsequent system upgrades. Secondly, the scientific goal was to extract dynamics (e.g. gravity and tidal waves) of the upper troposphere and stratosphere. The ST radar was run in a constant wind profiling mode throughout the entire run.

METHODOLOGY

Changes to the Doppler Rayleigh lidar include a refitted laser transmitter and extensive changes to data acquisition and instrument control systems. The laser, Continuum model YG682-20, was refitted to double the repetition rate to 40 Hz. Data acquisition and instrument control are done through a PC interface to an EG&G multi-channel scalar and a CAMAC crate. The PC replaced the previous lidar control that used a Micro PDP-11/83.

During the September run we operated the 532 nm lidar with the 430 and 47 MHz radars. We experimented with two lidar data acquisition modes. The first was a wind profiling mode, which used a pressure scanned Fabry-Perot interferometer to resolve the Doppler shift of the return signal. The long spectral integration (15-20 min) used for the wind mode requires ideal sky conditions. Our second mode was to measure higher spatial and temporal resolution vertical density profiles on nights when the skies were less than optimum. The radar was available for five of the nights and ran in a single tropospheric/stratospheric wind mode for the experiment.

ANALYSIS

The winds mode was hampered by spectral instabilities and start up difficulties with the new instrument control system. We believe the most significant causes of spectral instability are due to thermal drift and hysteresis problems with the pressure scanned Fabry-Perot. A further difficulty is the lack of an absolute frequency reference which complicates the task of establishing an exact Doppler zero. This experiment has set the stage for our next round of improvements. These improvements, currently under development, include the use of a piezo scanned Fabry-Perot and two color seed laser. It is expected that the new Fabry-Perot will defeat problems of thermal drift and hysteresis present with the pressure scanning instrument. The two color seed laser will give an absolute reference frequency as a zero Doppler shift calibration.

We have concentrated our analysis on one particular night during which the lidar was used as a vertical profiler and the stratospheric radar was used in a four point off-cardinal wind profiling mode. For this night, Sept 14-15, 1994, simultaneous lidar and radar observations began at 21:30 and ran until sunrise at 05:50 LT. We began observing in the wake of a large cumulus thunder head which passed overhead at 20:45 LT. The remainder of the anvil top is clearly seen in Fig. 1 centered at 13km, and extending until 24:30. The layer near 15km extending from 01:30 to 03:30 is an aerosol layer which we speculate is either cirrus

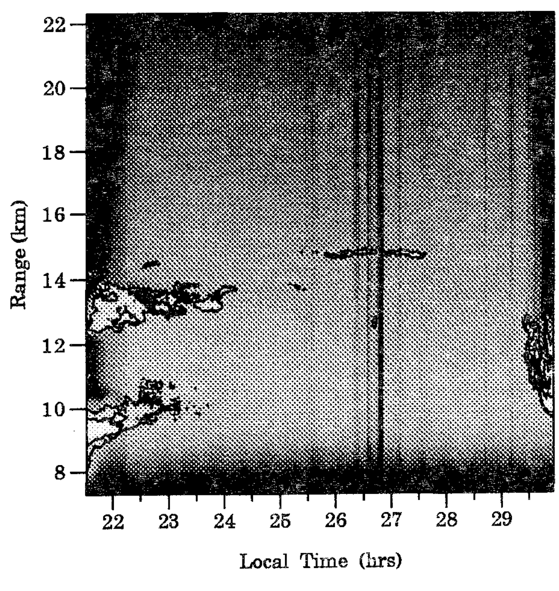

Fig. 1: Arecibo Rayliegh lidar raw data for Sept 14-15, 1994. Contours set to highlight cloud and aerosol features.

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cloud or dust from the Sahara desert.

For reference, Fig. 2 shows the average temperature and horizontal winds as determined from the daily San Juan Airport balloon data. The plot shows the average of two balloon flights; 19:00 Sept 14 and 07:00 Sept 15, 1994. Comparisons with the Arecibo ST radar winds and balloon winds are known to have shown good agreement [1].

Tropospheric and stratospheric density perturbations were retrieved by using a method outlined by *Meriwether* [2]. He uses two levels of fitting and normalization to account for high voltage gain modulation associated with the electronic gain switching of the PMT. We adapted this method to eliminate the effect aerosols in the retrieval of density perturbations.

Raw lidar data were collected with 30m range resolution and 75s integration time (Fig. 1). The data are first corrected to remove an average background level then a range square correction is performed. The first fit is a fourth order polynomial fit to the log of the nights clear sky average profile. The corrected individual profiles are then ratioed to this fit.

To estimate density perturbations above these aerosol layers, the layers were clipped using a threshold level from the ratioed profile (Fig. 1) before doing the second fit. The data are first averaged over 24 profiles to match the temporal resolution, 30 min, of the radar. A 3rd order polynomial is then fit to the aerosol clipped profiles. The difference between the clipped ratio and the second polynomial fit are the density perturbations. The density perturbations are smoothed by averaging over five range bins.

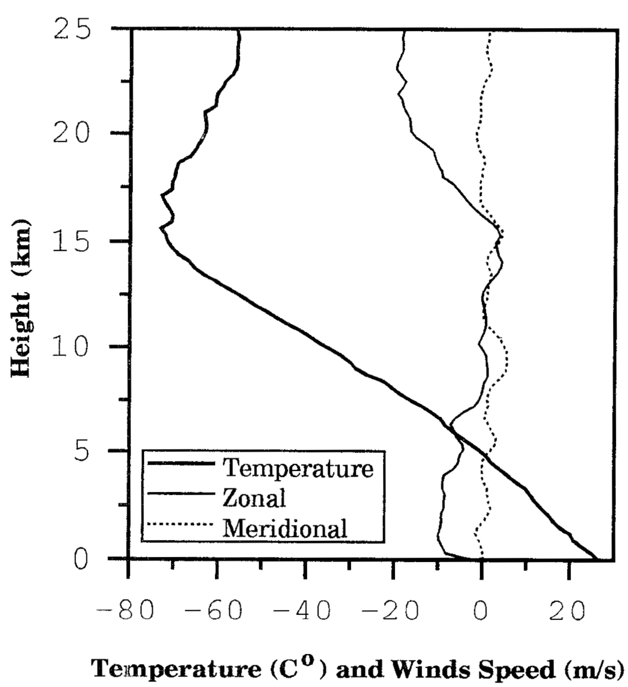

Fig. 2: San Juan Balloon data, temperature and winds, averaged over two flights; 19:00 Sept. 14 and 07:00 Sept. 15, 1994. The winds are positive eastward and northward.

The smoothed density perturbations are shown in Fig. 3 with 150m range and 30min temporal resolutions. While this method can not completely remove the effects of aerosols, as evident by the large fluctuations seen below 15km (Fig. 3), it provides a means of accessing data above the tropopause during less than perfectly clear observing conditions.

Stratospheric radar data have been analyzed for zonal and meridional wind field perturbations. Fig. 4 shows the zonal and meridional wind fluctuations for the night of Sept 14-15, 1994 The vertical resolution is 300m, and the temporal resolution is about 30 min.

DISCUSSION

Fig. 4 shows a downward phase propagation of both the zonal and meridional perturbation wind fields above the tropopause with a relative phase shift in altitude of about 90°. The rotational sense is clockwise with increasing height, suggestive of an upward-propagating gravity wave [3][4]. The lidar data does not show any such obvious wave activity.

A consistent negative density perturbation, or temperature enhancement [2], on the order of a few percent is observed by the lidar at the tropopause. This agrees with the temperature enhancement of a few percent illustrated by the balloon data, Fig.2. A comparison with the meridional wind perturbations suggests that a standing wave pattern is present below this altitude. Such a quasi-stationary wave structure could be generated by the interaction of a persistent wind and temperature field with mountain waves produced by orographic features of Puerto Rico [5].

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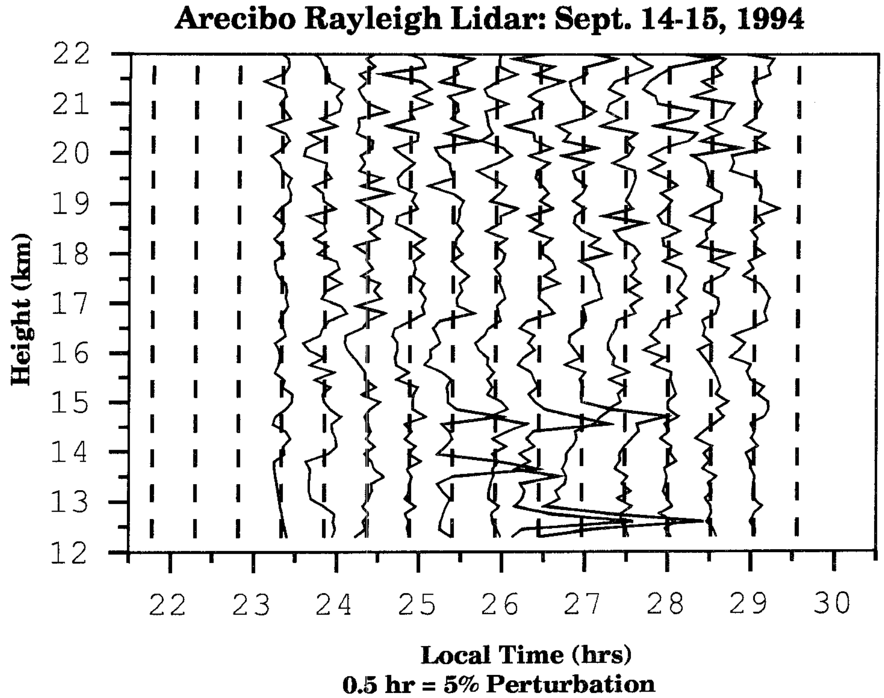

Fig. 3: Rayleigh lidar density fluctuations. Data were spatial averged to 150m resolution, and temporally to 30 min to match the radar.

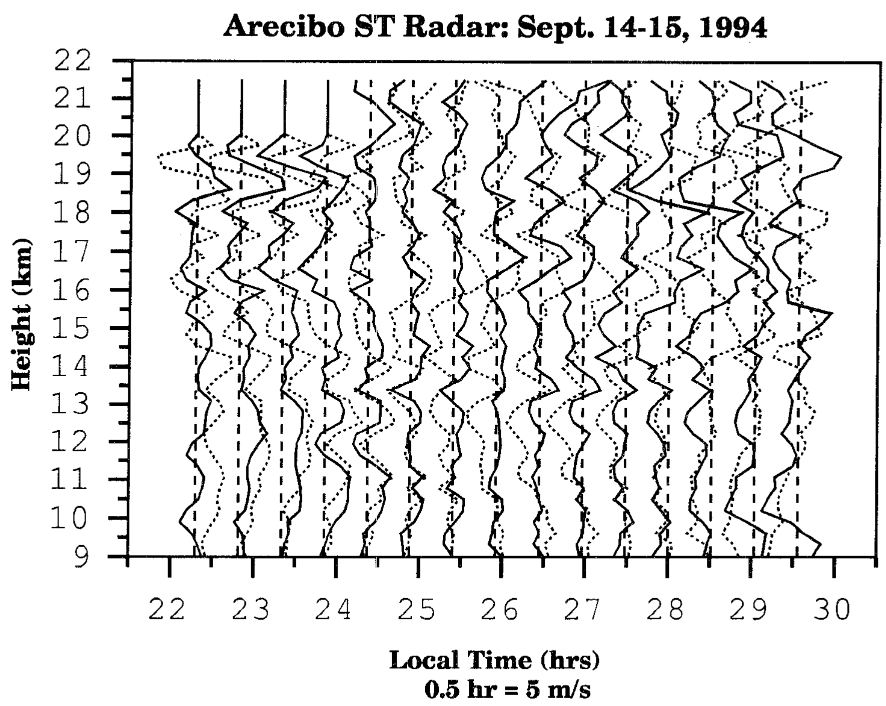

Fig. 4: Arecibo stratospheric/tropospheric radar zonal (solid) and meridional (dotted) wind fluctuations . These data represent 300 m and 30 min range and time resolutions respectively.