11.4 FRONTAL GENERATION OF WAVES IN THE STABLE BOUNDARY LAYER: CASES-99 OBSERVATIONS

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1. INTRODUCTION

One of the goals of the Cooperative Atmosphere-Surface Exchange Study 1999 field program (CASES-99) was to explore the role of inertial oscillations (IO) in the dynamics of the stable boundary layer. IOs are inertia-gravity waves confined to the horizontal plane. They have a frequency equal to the local Coriolis frequency, $f = 2\Omega \sin \phi$, where Ω is the rotation rate of the Earth and ϕ is latitude. Although IOs are thought to be generated by the evening transition of the boundary layer (Blackadar, 1957) observations of IOs in the atmosphere are few and mostly associated with frontal passages (Mori, 1990; Ostdiek and Blumen, 1997).

Five boundary-layer wind profilers (marked by squares and circles in Figure 1) were operated during CASES-99 by the Argonne Boundary Layer Experiment and the National Center for Atmospheric Research. Hourly wind speed and wind direction data at 60 m range gates from 100 m to 2 km are available; co-located sodars which provide winds from 10m to 200m at 5m range gates are available at the Argonne sites.

Both wind profiler and sodar data from all sites are analyzed for the presence of strong-amplitude IOs . To avoid contamination by diurnal oscillations possibly caused by the thermal wind oscillation over the sloping Great Plains, a two-step filtering process is applied to each time series. A diurnal filter ($_\mathrm{D}$) is convolved with the original time series u to calculated u_D, which is then subtracted from the original time series. Then an inertial filter ($_\mathrm{I}$) is convolved with this second time series to obtain $(u - u_\mathrm{D})_\mathrm{I}$. This time series is used for all future analysis.

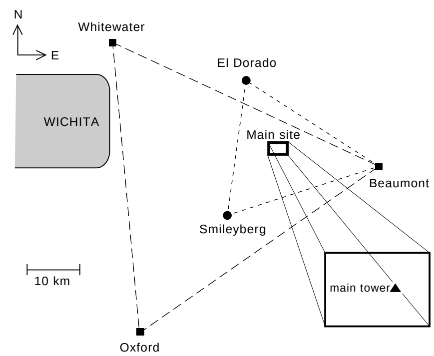

Figure 1: The CASES-99 observational domain in southeastern Kansas. Figure from Blumen et al, 2001.

2. DATA ANALYSIS TECHNIQUE

Complex demodulation (Bloomfield, 1976) is a local Fourier analysis that allows the exploration of waves of a known frequency but with unknown and slowly changing amplitudes and phases. As the inertial frequency f is known, the complex demodulation technique is well-suited to an investigation of large-amplitude IOs (Mori, 1990).

At each height z under consideration, a complex wind series $W(z,t) = u(z,t) + iv(z,t)$ (where u and v are the twice-filtered zonal and meridional winds) is calculated and frequency-shifted by multiplying by $\exp(ift)$. $W \exp(ift)$ is integrated over time, and the magnitude of the result is the amplitude of the IO over that time period. For this study, W is integrated over a 48-hour period as the inertial and diurnal filters involved coefficients over 48 hours.

Figure 2 depicts the results of complex demodulation when applied to a synthetic time series of u and v winds. This synthetic time series simulates a possible situation with low-level (amplitude of 1 m s^{-1}) IOs lasting for several days. On the fourth day, the IO amplitude increases dramatically to 4 m s^{-1} and then slowly decrease. This synthetic time series thus simulates one possible effect of a frontal passage to test the performance of the complex demodulation technique.

As seen in Figure 2, when amplitudes change rapidly

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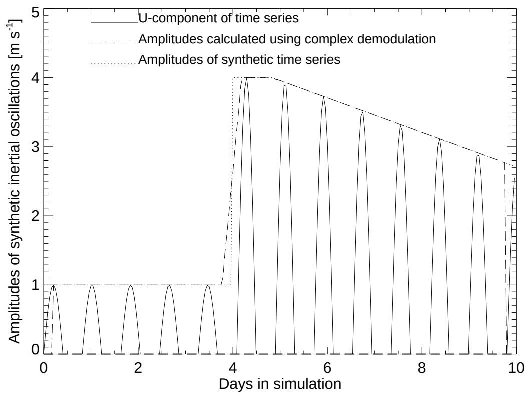

Figure 2: Amplitudes retrieved using the complex demodulation technique on synthetic inertial oscillations.

as on day 4, half a period is required for the complex demodulation technique to "catch up" to the IOs oscillations. For the slow decay process, as seen in days 5-10, the technique captures the synthetic IOs.

3. DISCUSSION OF RESULTS

The complex demodulation technique is applied to time series from 0000 UTC 3 Oct to 2300 UTC 30 Oct 1999. Each level of wind profiler data at each profiler is treated as an independent time series, as is each level of sodar data. Amplitudes greater than 1 m s^{-1} are considered significant. Four distinct periods of significant amplitudes appear in Figure 3 (Oxford results) and in the datasets from the other profilers: 16 Oct, 22 Oct, 13 Oct, and 29 Oct (listed in decreasing order of the peak amplitude for each episode). During the month of October, four fronts passed the CASES-99 array, on the same days listed above. The large-amplitude IO events are correlated with frontal passages.

4. CONCLUSIONS AND ONGOING RESEARCH

Analysis of boundary-layer wind profiler data from the CASES-99 experiment indicate that IOs can be observed near the time of surface frontal passages. Ongoing research is exploring if the complex demodulation technique can distinguish the onset time of IOs to more closely identify them with frontal passages and the generation of other inertia-gravity waves.

Analysis of an expanded dataset, using four years (1997-2000) of profiler and sodar data from the Argonne Boundary Layer Experiment, is also underway to identify episodes of high-amplitude IOs. Preliminary analysis indicates that of 33 such episodes, each case is associated with either a frontal passage or a shear line in a low pressure trough.

5. ACKNOWLEDGMENT

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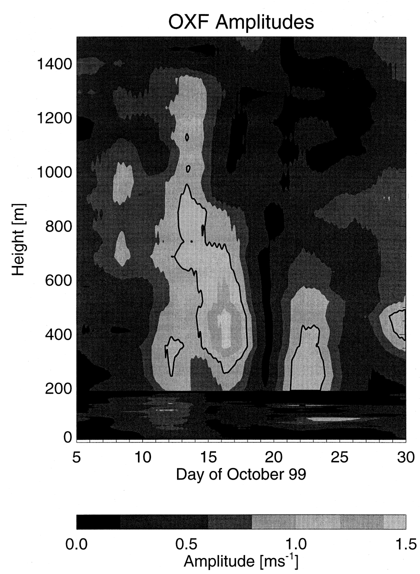

Figure 3: Time-height cross section of IO amplitudes calculated using complex demodulation on the Oxford profiler/sodar dataset.