Boundary Layer (BL) Thermal Eddies over a Pine Forest in CARES 2010

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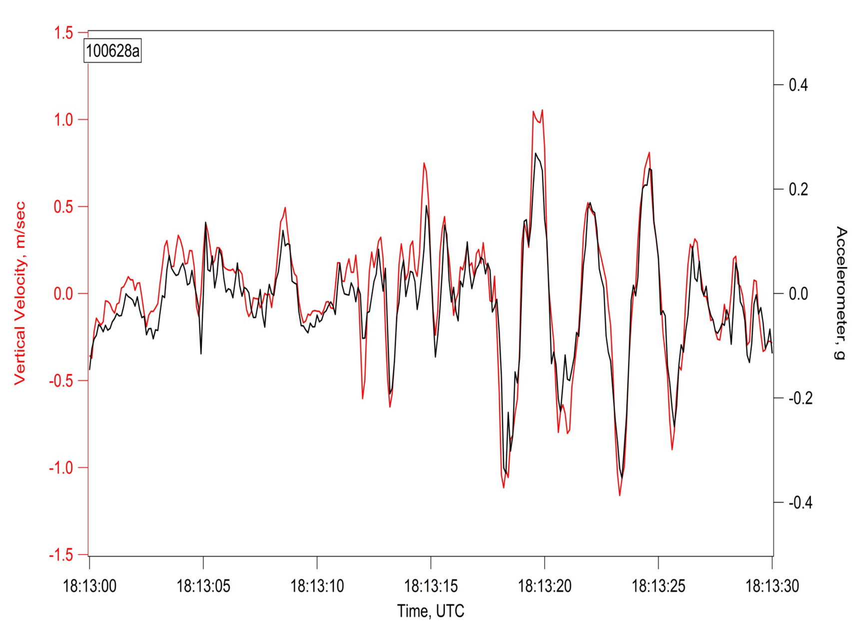
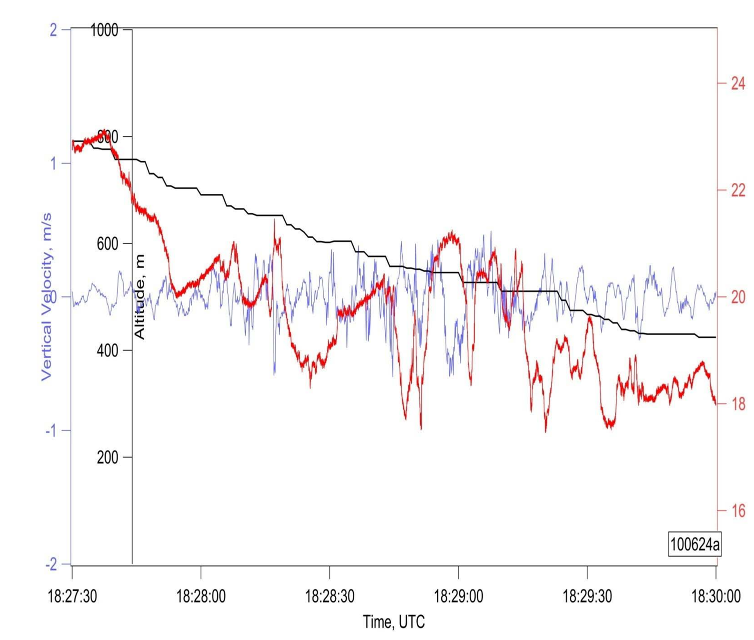
Measurement of Vertical Velocities



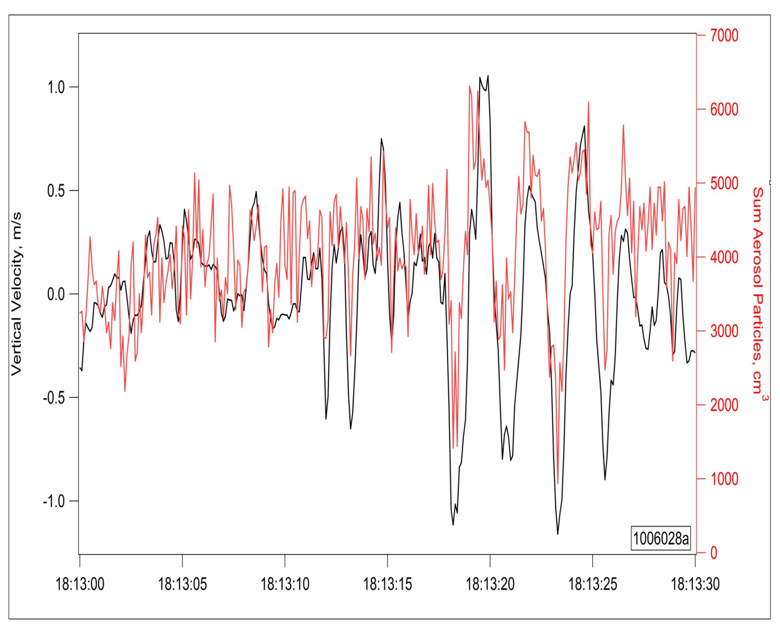
The Gulfstream G-1 research aircraft (AAF) participated in the CARES 2010 field campaign. Onboard was the BNL high-sensitivity gustprobe and the BNL accelerometer. These two instruments provided two independent methods for measuring the vertical velocity in the BL. These were both sampled at 200Hz, and after signal processing to remove the aircraft motion the data was averaged to 10 meter resolution. The gustprobe vertical velocity resolution was 0.1cm/sec and 0.25cm/sec for the accelerometer. As seen in the figure the agreement in the calculated vertical velocities from the two methods was excellent.

Correlation with Potential Temperature



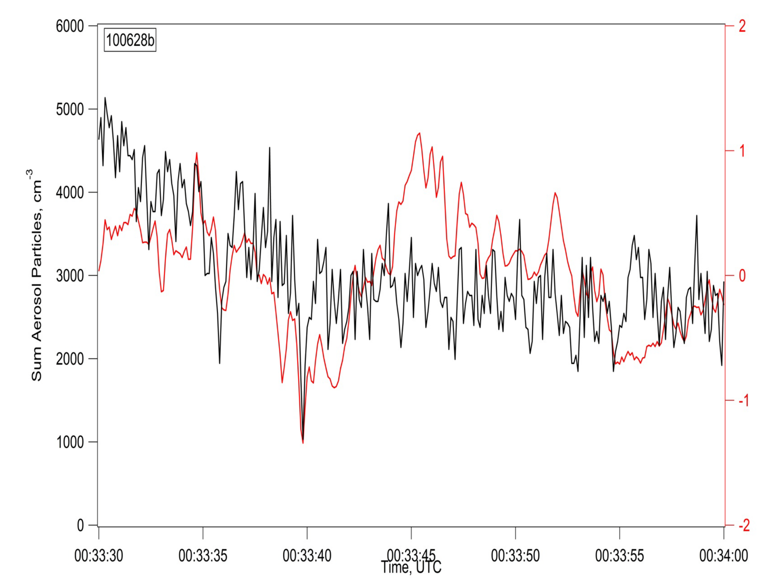
It would be expected that the vertical velocities should also be correlated with other microphysical and aerosol measurements from the G-1. Unfortunately with the exception of the UHSAS and physical state variables, all of the measurements are at 1Hz or 100 meters spatial resolution which cannot resolve the thermal eddy structure of the BL. One state variable, the potential temperature did correlate with the vertical velocity, as is shown in the figure, taken from morning flight of June 14. The G-1 was descending, as is shown by the black elevation trace. The potential temperature of the air above the BL was about 20C, whereas the BL potential temperature was about 18C. The vertical velocities and the potential temperature are anti-correlated, downdrafts are transporting air with a higher potential temperature into the cooler BL.

Vertical Velocity Effects on Aerosol Particle Concentration



An aerial UHSAS (Ultra High Sensitivity Aerosol Spectrometer) which was an ARRA purchase, was onboard the G-1. The UHSAS measured the aerosol particle concentrations from 55 to 1000 nm diameter, sized into 100 bins at 10 Hz time resolution. The left axis is the vertical velocity in m/sec. The right axis, shows the sum of all aerosol particles, per cc as measured by the UHSAS versus time. This is a 3 km segment flown in the BL over a pine forest east of Sacramento,CA, the most easterly leg of the sampling flight plan. Note the high degree of correlation between the vertical velocity and the total number of aerosol particles. The 3 sets of downdrafts/updrafts starting at 18:13:18 UTC are 3 thermal eddies, about 250 meters wide, in the BL. These were observed during the morning flight of June 28.

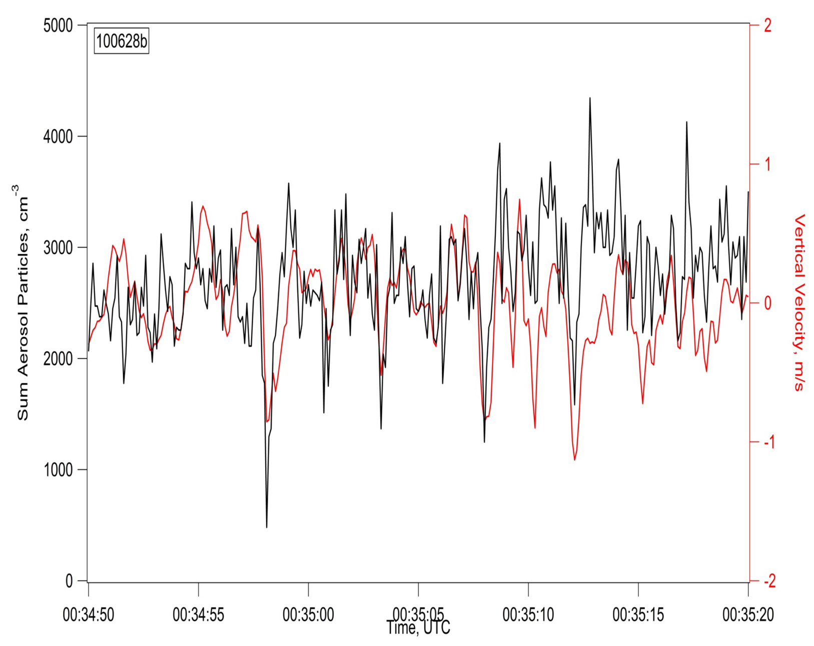
Poor Correlation



The correlation between the aerosol particle concentrations and vertical velocities was observed predominately in the morning flights, when the BL height was not high. An example of a poor or non existent correlation is shown in the figure, again from the June 28 afternoon flight. Here there is a broad updraft region, but no increase in aerosol particle concentration.

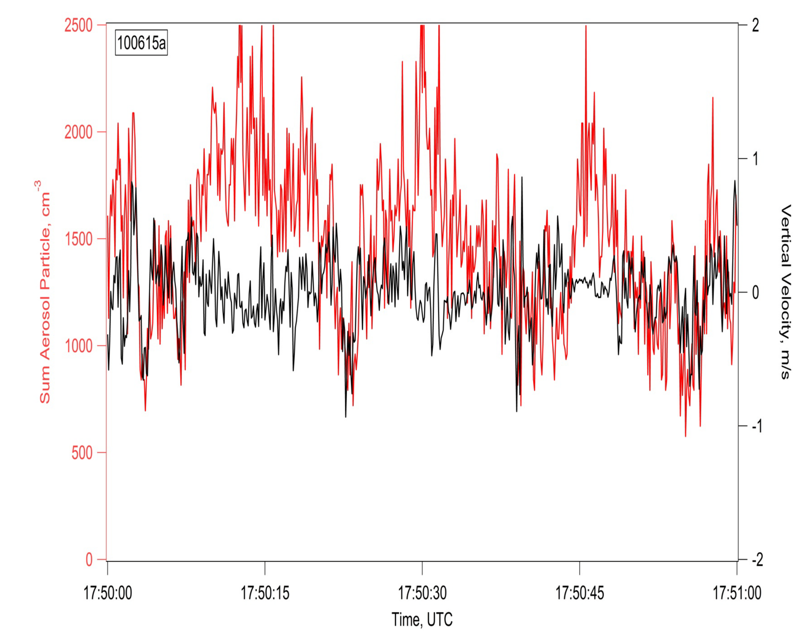
There are other sampling periods in CARES when the aerosol particle concentrations were dominated by automotive emissions, with no observable correlation with vertical velocity.

Seven Thermal Eddies in Three Kilometers



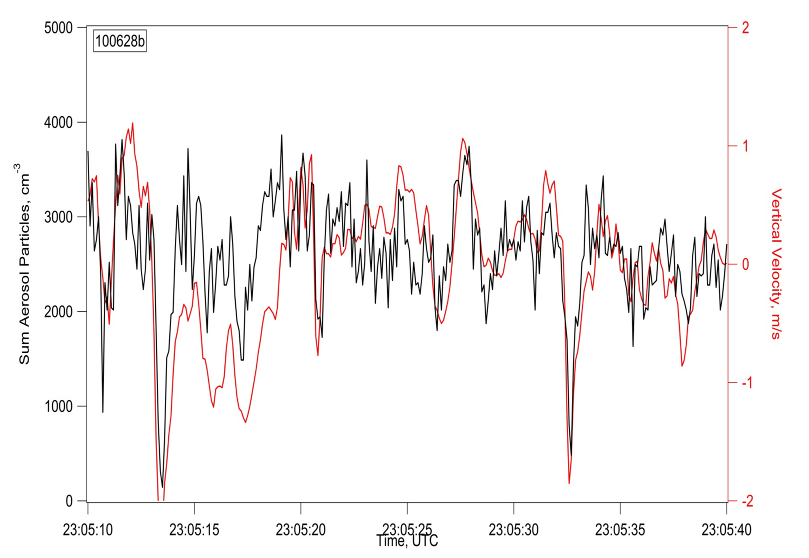
There are seven thermal eddies shown in the figure, which were observed in the afternoon flight of June 28. Again, these thermal eddies are about 250 meters wide. These thermal eddies are formed at the surface from the intense solar heating. These thermal eddies form the BL and the continuing formation of thermal eddies at the surface help raise the height of the BL as they progress up through the BL. The eddy updrafts are transporting aerosol from the pine forest surface, thus the observed increase in aerosol particle concentration. The eddy downdrafts are transporting relatively aerosol free air from just above the BL, diluting the observed aerosol particle concentrations.

"Residual Aerosol Layer" above the BL



Another poor correlation between the vertical velocity and aerosol concentration was observed on the morning flight of June 24. Here the G-1 is sampling about the top of the BL, it is moving in and out of the BL. There is almost twice as much aerosol above the BL (regions of low vertical velocities), and this was the "residual aerosol layer" which laid right on top of the BL. The residual layer was transported overnight from either the bay area or from the pine forest to the east. More thermal eddies would be formed as the insolation increased through the morning, which incorporated this residual layer into the heightening BL. By the afternoon flight this layer was gone since it was now mixed into the BL. This residual layer was observed on several other days.

Intense Downdrafts



Intense downdrafts are observed more frequently in the BL than intense updrafts. The figure shows two intense downdrafts, the one on the left is about 50 meters wide and the one on the right is about 30 meters wide. These downdrafts do not appear to be part of a thermal eddy. Nonetheless, these downdrafts are diluting the aerosol particle concentrations to 5 to 10% of their BL concentrations with air from above the BL.

These intense downdrafts can only be observed with high spatial resolution,10 meters for the UHSAS and vertical velocities. G-1 conventional spatial resolution,100 meters, would smear this BL structure, leading to the incorrect assumption that the BL is more well mixed than it really is.

Conclusions

- Thermal eddies have been observed in the BL during the CARES 2010 field experiment, made possible only by the 10 meter spatial resolution of the gustprobe, accelerometer and UHSAS.
- The thermal eddies are most prominent on days with high insolation and in the morning with lower BL heights.
- These data can be used to calculate aerosol particle fluxes from the pine forest into the BL.
- This BL structure cannot by observed by conventional G-1aircraft instrumentation with100 meter spatial resolution. The BL is not that well mixed as would be inferred from lower resolution measurements.

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