Comparison of Mixed-layer Heights from Airborne HSRL and WRF-Chem During CARES

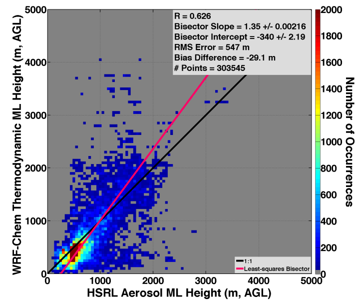
Research Highlight

The NASA Langley Research Center (LaRC) airborne High Spectral Resolution Lidar (HSRL) was deployed to California on board the NASA LaRC B-200 aircraft to aid in characterizing aerosol properties during the California Research at the Nexus of Air Quality and Climate Change (CalNex) and Carbonaceous Aerosol and Radiative Effects Study (CARES) field campaigns in May and June 2010. The referenced paper describes the modified Haar wavelet covariance transform method used to derive the mixed-layer (ML) heights from HSRL backscatter profiles. The extensive suite of measurements and modeling during these campaigns presents the opportunity for assessing the Weather Research and Forecasting (WRF) model coupled with Chemistry, or WRF-Chem model, in this region and presents insight into horizontal variability of ML height and the representativeness of localized ML height measurements. The HSRL ML heights are validated using ML heights derived from two radiosonde profile sites operated during CARES. The HSRL ML heights are also used to evaluate the performance in simulating the temporal and spatial variability of ML heights from the Weather Research and Forecasting Chemistry (WRF-Chem) community model.

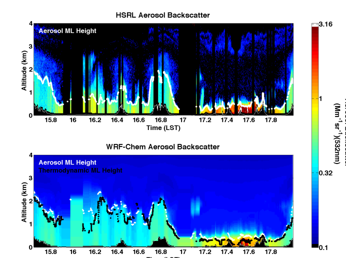
The CARES campaign in the Sacramento region provides the opportunity for verifying the applicability of HSRL-derived aerosol ML heights by validating them with thermodynamic ML heights derived from radiosondes launched at the T0 and T1 ground sites. Good agreement is found from comparing HSRL and radiosonde ML heights and supports the use of the HSRL-derived aerosol ML heights for investigation of spatial variability and evaluation of the WRF-Chem model. Hourly WRF-Chem simulations are extracted along the HSRL flight track using the Aerosol Modeling Testbed software tools. This provides a direct comparison of matched times and locations between HSRL and WRF-Chem. During CARES, WRF-Chem under-predicted the ML heights when the ML height is low, but tends to over predict when the ML height is large (see image on top right).

A potential factor affecting the accuracy of the WRF-Chem simulation is the complexity of the terrain. To investigate this further, the CARES domain was split into three regions#San Francisco Bay, Central Valley (that includes Sacramento and the T0 ground site), and Sierra Nevada (includes the T1 ground site)#for analysis of the ML height values from both HSRL and WRF-Chem. While there are differences, it is not clear that WRF-Chem performs significantly better or worse in one region or another, but the investigation revealed some patterns in the comparisons that are instructive. There is generally good agreement over the flat terrain in the Central Valley, but on certain days WRF-Chem does not correctly represent the diurnal growth of the mixed layer and distributes aerosol over a much taller ML than measurements indicate, up to twice the measured ML height. In contrast, the complex terrain and bodies of water in the San Francisco Bay and Sierra Nevada regions introduce larger uncertainties in the simulated interaction of surface fluxes, boundary layer mixing, and ambient winds or there are local variations in the ML depth that the model cannot resolve using a grid spacing of 4 km.

In order to make a more direct one-to-one comparison and separate potential issues with ML height determination from errors in the simulation of aerosol, another experiment was performed where ML heights from WRF-Chem simulated backscatter are compared to the HSRL ML heights for the CARES flights. Although the WRF-Chem simulations of aerosol backscatter and aerosol ML height are generally in good agreement with the HSRL measurements, the simulations sometimes have difficulty in accurately forecasting the vertical extent of aerosols in the ML as well as the magnitude of aerosol backscatter both in the ML and the free troposphere (see image on bottom right).



Scatter and bisector regression plot of WRF-Chem thermodynamic ML and HSRL aerosol ML heights across all flights during CARES. The PBL heights for WRF-Chem are derived from potential temperature. Number of occurrences in each histogram bin is shown in color. Bias and RMS Difference calculated WRF-Chem # HSRL. The number of points in these comparisons corresponds to the HSRL resolution of the backscatter profiles for the 23 CARES flights (1 point # 1 km of airborne HSRL data).



Data shown here from the second research flight on 14 June 2010. (Top) aerosol backscatter measured from HSRL with aerosol ML heights derived from aerosol backscatter. (Bottom) simulated aerosol backscatter from WRF-Chem with thermodynamic ML heights (in black) and aerosol ML heights (in white).

The results presented here demonstrate that the aerosol ML heights derived from HSRL aerosol backscatter profiles are closely comparable to those derived from radiosonde temperature profiles and that these HSRL ML heights can be used to evaluate ML heights from models. The HSRL aerosol ML heights provide additional information for validating and improving model ML heights by providing the means to distinguish between biases due to BL parameterizations from those due to other factors such as interaction with synoptic meteorology.

Reference(s)

Scarino AJ, MD Obland, JD Fast, SP Burton, RA Ferrare, CA Hostetler, LK Berg, B Lefer, C Haman, JW Hair, RR Rogers, C Butler, AL Cook, and DB Harper. 2014. "Comparison of mixed layer heights from airborne high spectral resolution lidar, ground-based measurements, and the WRF-Chem model during CalNex and CARES." Atmospheric Chemistry and Physics, 14(11), doi:10.5194/acp-14-5547-2014.

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Aerosol Life Cycle