A Length-Scale Analysis of Variance for Many Constituents from Aircraft, Satellite and Model Results During the 2013 SENEX Field Study

S. McKeen[1,2], R. Ahmadov[1,3], N. Smith[4], A. Gambacorta[4], G. Frost[2], S. Kim[1,2], Y. Cui[1,2], B. McDonald[1], W.M. Angevine[1,2], M. Trainer[2], J. Peischl[1,2], T. Ryerson[2], C. Barnet[4] and R.B. Pierce[5]

[1]Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, CO 80309; 303-497-5622, E-mail: Stuart.A.McKeen@noaa.gov
[2]NOAA Earth System Research Laboratory, Chemical Sciences Division (CSD), Boulder, CO 80305
[3]NOAA Earth System Research Laboratory, Global Systems Division (GSD), Boulder, CO 80305
[4]Science and Technology Corporation, Boulder, CO 80305
[5]NOAA National Environmental Satellite, Data, and Information Service (NESDIS), Advanced Satellite Products Branch, Madison, Wisconsin 53706

A useful perspective for analyzing the temporal or spatial variance of a time series measurement is by decomposing the signal into orthogonal functions that depend on the sample interval or length-scale. The fractal nature of free atmospheric turbulence is the determining factor in the scale dependence of variance, and has been found in previous studies to affect chemical constituents in the same manner as standard meteorological quantities. Fourier analysis of 8 constituents collected at 1 Hertz by the NOAA W-P3 aircraft during the 2013 Southeast Nexus (SENEX) field campaign are analyzed in terms of slopes of the power spectral density (PSD), focusing on the 25 to 200 km length-scale range. When spectra are averaged over several 500 mb flight legs, a very linear dependence is found on log-log plots of PSD versus inverse length-scale, with slopes varying within ±30%, and close to the slope of -5/3 predicted from dimensional scaling theory of isotropic turbulence. A similar analysis is applied to WRF/Chem model results and observations derived from NOAA's Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) instruments from the Visible Infrared Imaging Radiometer Suite (VIIRS) by NOAA Unique Combined Atmospheric Processing System (NUCAPS), including profiles of temperature, water and several trace gases (e.g. O_3, CO, CH_4, CO_2, HNO_3, SO_2, and N_2O). Comparisons with the aircraft data shows the model accounts for variance on length-scales greater than ~6ΔX, where ΔX is the model horizontal resolution (12km). The model length-scale dependence of variance in the 200 to 1000 km range is quite similar to that of the NUCAPS retrievals for many variables and is likewise consistent with the expected -5/3 power law scaling of isotropic turbulence. Several gas phase species from NUCAPS show a length-scale dependence inconsistent with the model and NUCAPS H_2O and O_3. A technique is provided to estimate the appropriate horizontal averaging lengths for those species that exhibit this inconsistency.

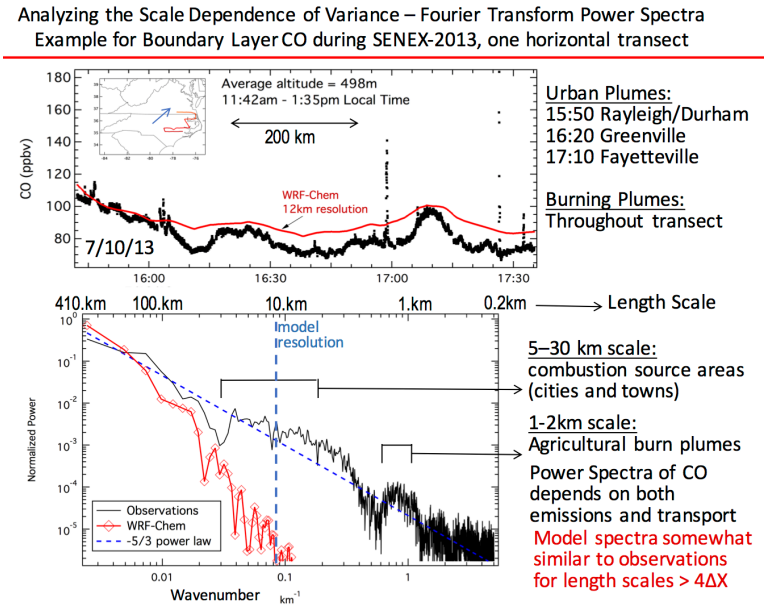

Figure 1. Example of time series and normalized Fourier power of CO from a NOAA-P3 aircraft transect over North Carolina during the 2013 SENEX campaign.