Continental scale: Ameriflux towers

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Temporal and spatial patterns in regional- and continental-scale CO_2 mixing ratio measurements

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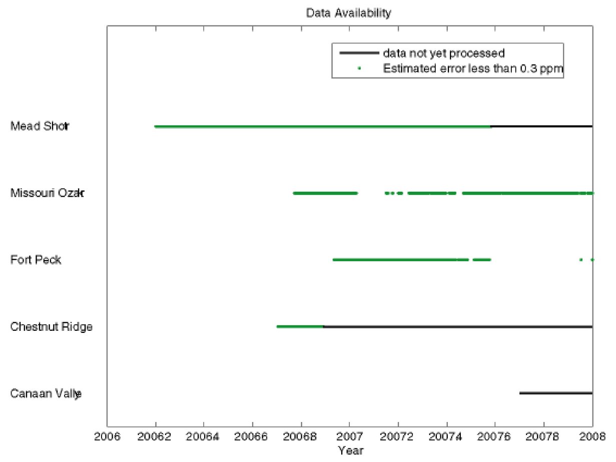
Continental scale: Ameriflux Towers

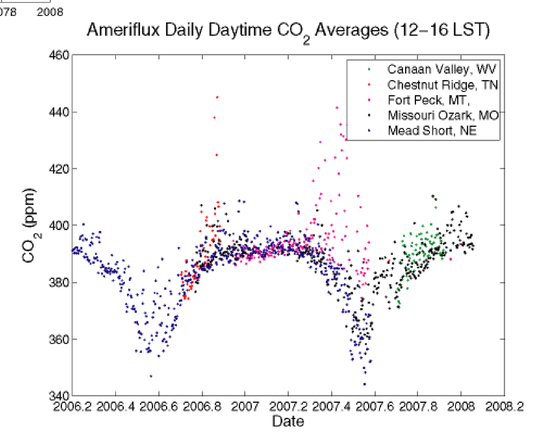
The study of the terrestrial carbon cycle is currently data limited. One approach to increasing the density of data over the continents is to instrument eddy-covariance flux towers with well-calibrated CO_2 mixing ratio measurements. More than two hundred such towers are currently being operated at continental sites around the globe. Most of these towers, however, while measuring CO_2 mixing ratios at high frequency, continuously, and with good relative precision, do not have carefully calibrated long-term mixing ratio measurements. Similarly it has been thought that mixing ratio measurements in the atmospheric surface layer, the lowest portion of the atmospheric boundary layer, would be too close to strong sources and sinks to be useful for studying the carbon cycle via atmospheric budget or inverse studies. Methods exist, however, for both precise calibration of flux tower mixing ratio measurements and careful interpretation of surface layer data.

Licor-820 based systems

A relatively low-cost, high-precision CO_2 mixing ratio measurement system has been developed in collaboration with NCAR-ATD, to support inverse analyses of the terrestrial carbon balance at regional to continental scales. The systems use LICOR-820 non-dispersive infrared analyzers rather than the more expensive, but lower noise LICOR-6262 or LICOR-7000, since fast time response is not required for this application and the noise of the LICOR-820 can be reduced sufficiently by averaging over two minutes. Two nafion driers are used, ensuring that the difference in water vapor concentration between the dried sample and the moistened calibration gases is less than 300 ppm (corresponding to an error in the $[CO_2]$ measurement of 0.1 ppm). Flow control, such that the flow rate changes by less than 4 cc/min between the sample and calibration gases, is achieved using a mini-regulator. Leak tests are automated and the systems are temperature controlled. Calibration with four tanks are performed every four hours. A target tank is sampled every hour and a long-term archive tank is sampled once daily.



Data availability for the five Ameriflux towers. Missing data is primarily due to low flow issues and LI-820 hardware failures.

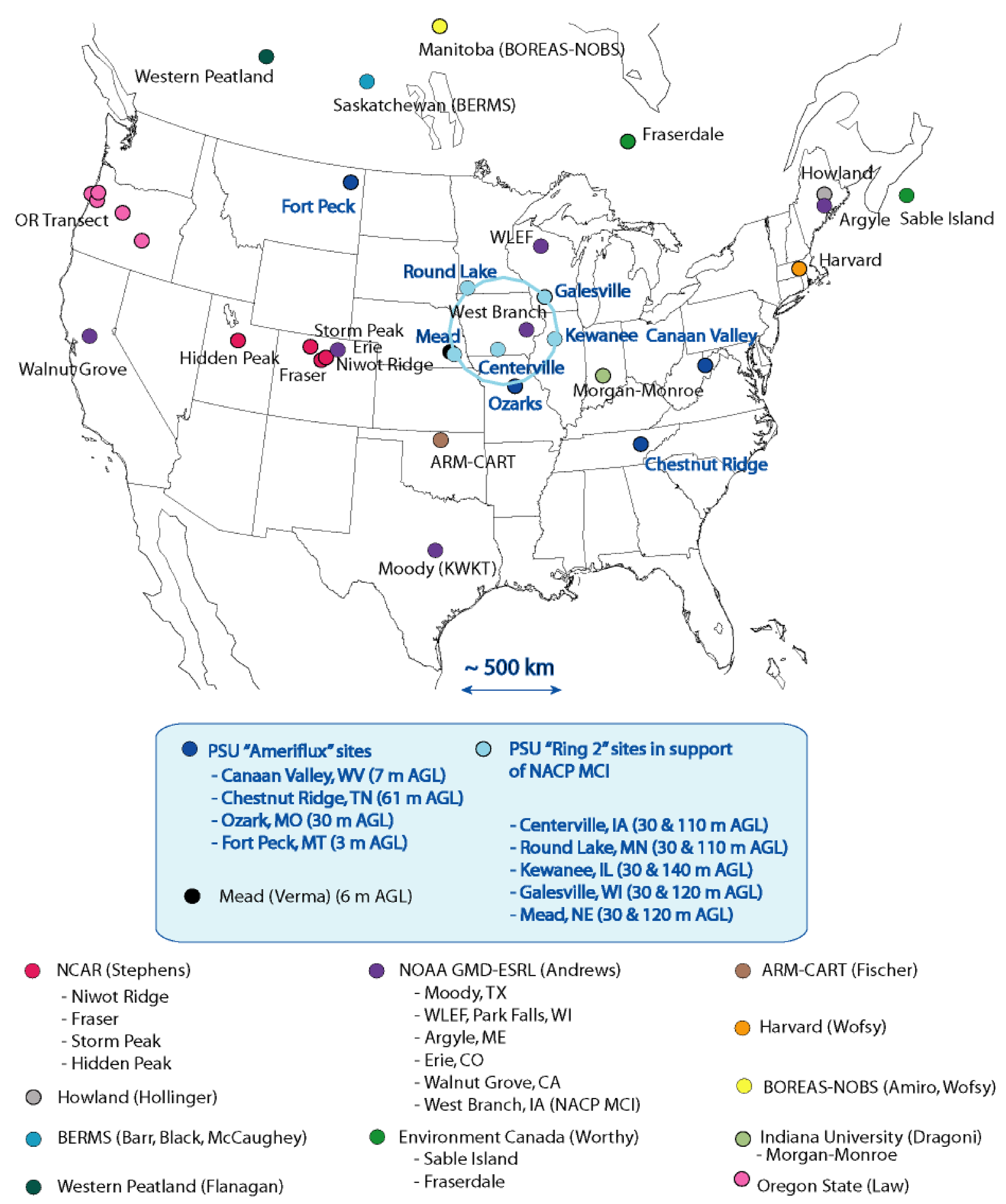


Daily daytime (12-16 LST) average CO_2 mixing ratio. Additional data are not yet processed.

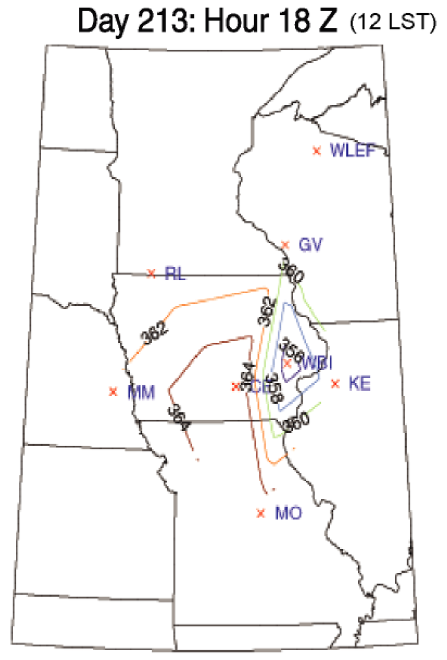
Continental-scale (Ameriflux towers)

* Data from five LICOR-based systems deployed on Ameriflux towers
  - Calibrated every 4 hours
  - Hourly target tank
  - Daily archive tank
  - Temperature control
  - Automated leak tests
* Available soon with precise calibration

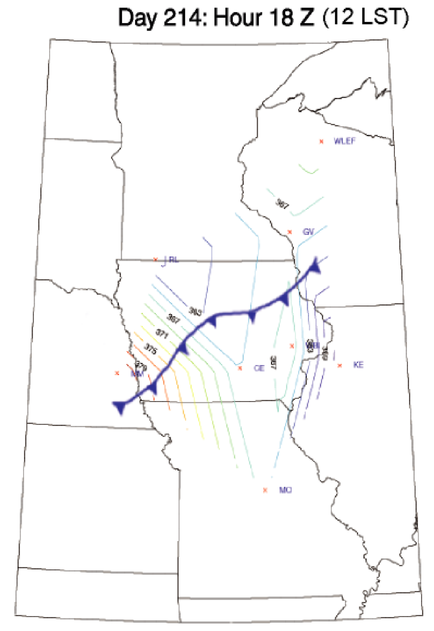
Continuous, Well-Calibrated CO_2 Measurements in North



Day 213: Hour 18 Z (12 LST)



Day 214: Hour 18 Z (12 LST)



CO_2 weather maps
- Ring 2
- NOAA ESRL
- Ameriflux

CO_2 "weather maps" for days 213 and 214 (August 1 and 2). On day 214 there was a frontal passage through the region. Data from Ring 2 (Centerville, Galesville, Kewanee, Mead, and Round Lake), Ameriflux towers (Missouri Ozark and another Mead site), NOAA-ESRL towers (West Branch and WLEF) are used. The pattern between the two days is similar at the two Mead sites (20 ppm increase between day 213 and 214), even though the Ameriflux Mead tower data has not been VTT-adjusted (virtual tall tower).

	Site	DOY 213: 12 LST	DOY 214: 12 LST
Ring 2	Centerville	366.09 ppm	364.93 ppm
	Galesville	360.35	366.28
	Kewanee	359.52	355.48
	Mead	362.29	383.77
	Round Lake	360.32	360.54
NOAA ESRL	WLEF	362.03	370.63
	WBI	354.55	368.27
Ameriflux	Ozark (30 m)	365.16	365.77
	Mead (6 m)	351.28	371.74

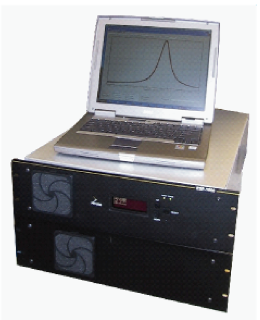
Regional scale: Ring 2 Towers

A central barrier preventing the scientific community from understanding the carbon balance of the continent is methodological; it is technically difficult to bridge the gap in spatial scales that exists between the detailed understanding of ecological processes that can be gathered via intensive local field study, and the overarching but mechanistically poor understanding of the global carbon cycle that is gained by analyzing the atmospheric CO_2 budget.

The NACP's Midcontinental Intensive (MCI) study seeks to bridge this gap by conducting a rigorous methodological test of our ability to measure the terrestrial carbon balance of the upper Midwest. A critical need in bridging this gap is increased data density.

Our work adds a regional network of five communications-tower based atmospheric CO_2 observations from April 2007 through October 2008 to the planned long-term atmospheric CO_2 observing network (tall towers, aircraft profiles, and well-calibrated CO_2 measurements on AmeriFlux towers) in the midcontinent intensive region. A primary goal of the project is to increase the regional atmospheric CO_2 data density so that 1) atmospheric inversions can derive well-constrained regional ecosystem carbon flux estimates and 2) the trade off between data density and accuracy of the flux estimates can be determined quantitatively using field observations, thus providing guidance to future observational network designs. The communications towers network is designed to "oversample" the atmosphere in the study region for more than a full year.

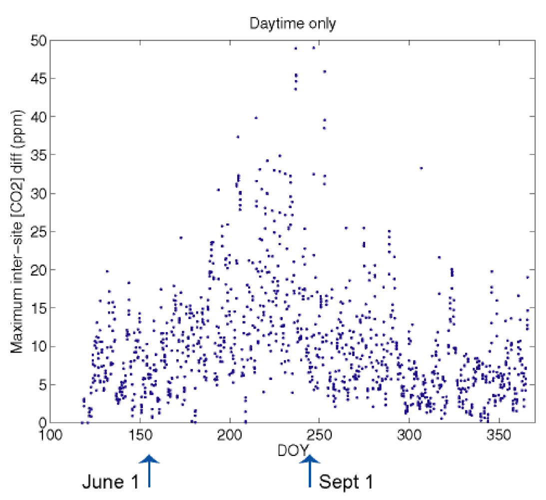
Cavity Ring-Down Spectroscopy

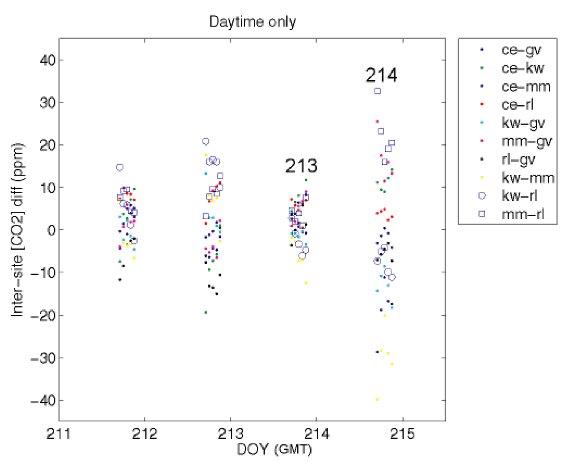


The regional network is composed of ultra-sensitive trace gas (CO_2, methane, CO) monitoring systems developed by Picarro, Inc. Advantages include:
* High accuracy and relative comparability
  - long-term stability: days to weeks
  - 1.5-sec sample precision and accuracy of ≤0.2 ppm
* No drying is required; water vapor is measured and correction to CO_2 is applied
* Stable and robust long-term measurement

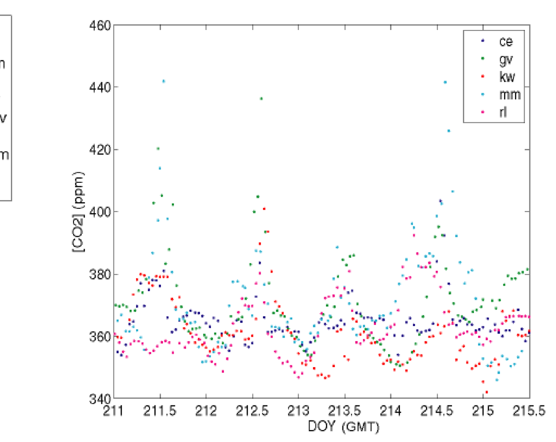
Spatial gradients

Maximum difference between each of the daily daytime (12-16 LST) average CO_2 mixing ratios for the five Ring 2 sites. During the growing season, the $[CO_2]$ at the site nearly always differs by more than 5 ppm, and sometimes by as large as 30-50 ppm.



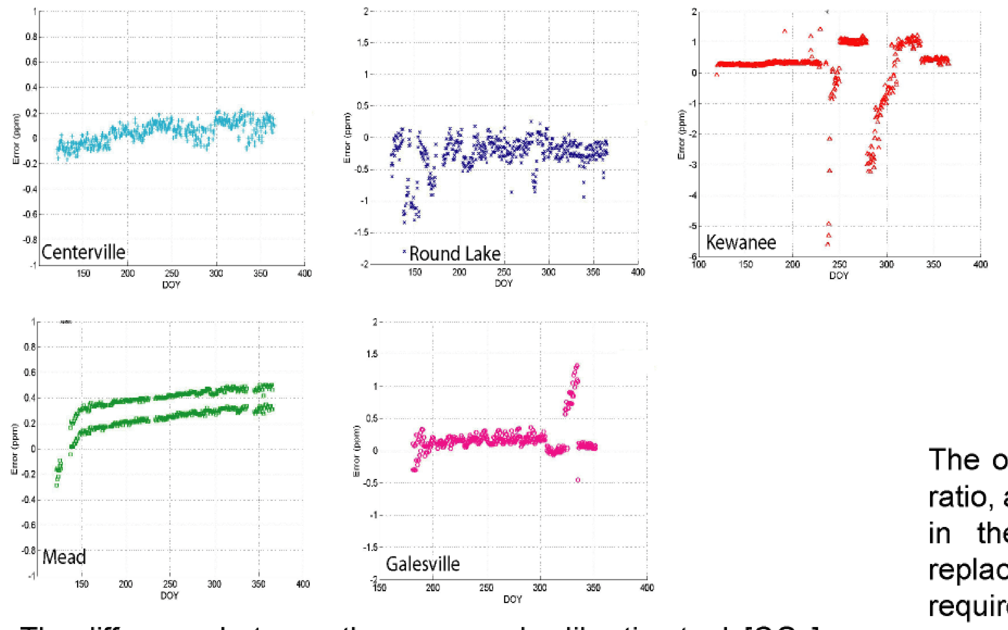


Focussing on a four-day period, the spatial gradient changes significantly between day 213 when the largest difference between sites is 12 ppm, and day 214 when Kewanee and Mead differ by almost 30 ppm.



CO_2 mixing ratios during the same four-day period.

Reference Gas Error *prior to calibration*

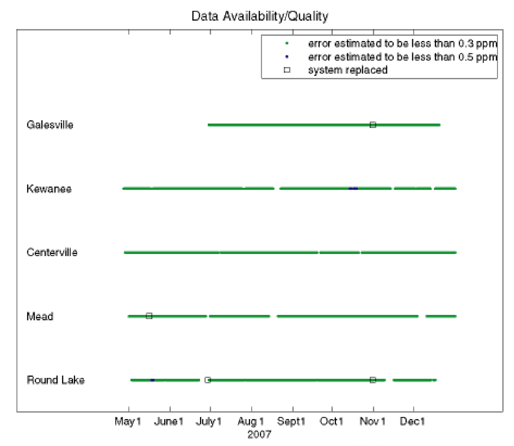


The difference between the measured calibration tank $[CO_2]$ and the known values, **using the initial pre-deployment calibration performed in April 2007**. Currently a best-fit straight line calibration is calculated for each daily file.

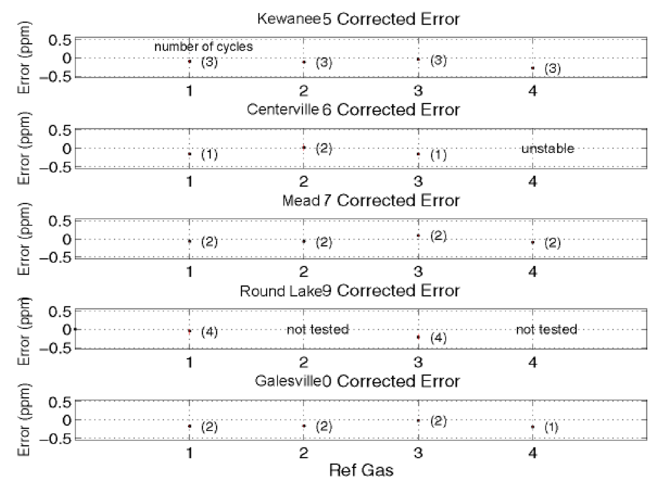
Round-robin tests

In February 2008 each of the five instruments was tested with NOAA-calibrated tanks (338.81, 369.39, 401.68, 431.78 ppm). The average error, after daily calibration, is shown in the figure to the left. All of the calibrated errors are less than 0.2 ppm except for gas 4 for Kewanee (0.28 ppm error) and gas 3 for Round Lake (-0.21 ppm error).

Estimated Error *post-calibration*

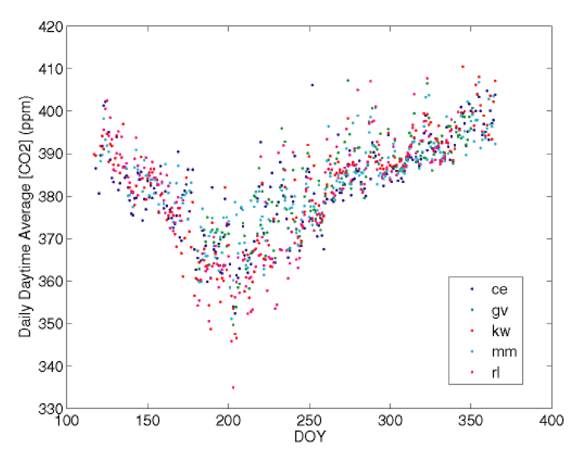


The overall estimated error in the CO_2 mixing ratio, after applying a daily calibration, is shown in the above figure. Several instrument replacements, as indicated, have been required to date.

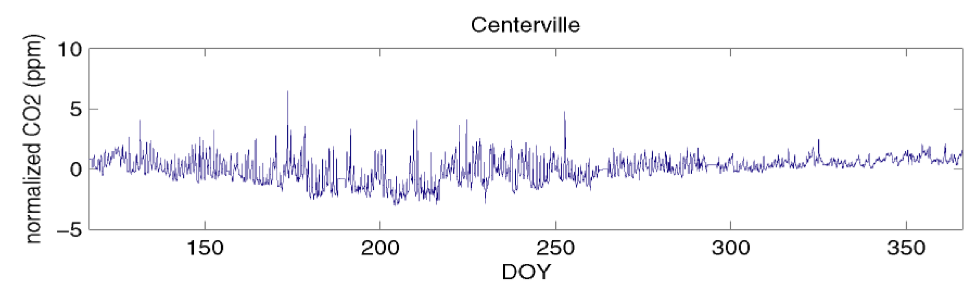


Overall patterns

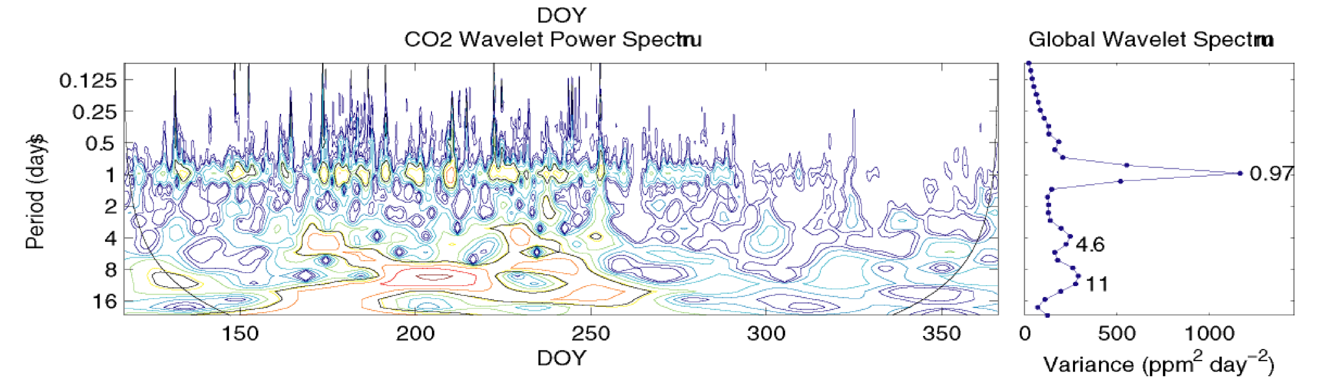
Daily daytime (12-16 LST) average CO_2 mixing ratio for the five Ring 2 sites. The average drawdown during the summer is 50 ppm, with significant synoptic variability. The horizontal gradients are large, particularly during the growing season.



ce = Centerville
gv = Galesville
kw = Kewanee
mm = Mead
rl = Round Lake



Normalized CO_2, gap-filled with a polynomial fit.



Wavelet power spectrum, indicating the dominant frequencies as a function of time, of the CO_2 mixing ratio time series at Centerville (Torrence and Compo, BAMS, 1998). Wavelet analyses of all five sites indicate decreasing variability in the fall, and a dominant peak at 1 day (diurnal cycle). At Centerville, there are also peaks at 4.6 and 11 in the global (i.e., time-averaged) energy-conserving wavelet power spectrum, which is perhaps attributable to synoptic variability. These peaks are more variable between the sites, with peaks occuring at 3.5 +- 1.2 days for four of the sites, and 11.6 +-1.8 days for four of the sites. Frontal passages between May 1 and Sept 30 for 2007 occured every 4.0 +- 2.2 days.