Estimates of Lower-Tropospheric Divergence and Average Vertical Motion in the Southern Great Plains Region

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ABSTRACT

Large-scale mean vertical motion affects the atmospheric stability and is an important component in cloud formation. Thus, the analysis of temporal variations in the long-term averages of large-scale vertical motion would provide valuable insights into weather and climate patterns.

915-MHz radar wind profilers (RWP) provide virtually unattended and almost uninterrupted long-term wind speed measurements. We use five years of RWP wind data from the Atmospheric Boundary Layer Experiments (ABLE) located within the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site from 1999 to 2004. Wind speed data from a triangular array of SGP A1, A2, and A5 ancillary sites are used to calculate the horizontal divergence field over the profiler network area using the line integral method. The distance between each vertex of this triangle is approximately 60 km. Thus, the vertical motion profiles deduced from the divergence/ convergence of horizontal winds over these spatial scales are of relevance to mesoscale dynamics. The wind data from RWPs are averaged over 1 hour time slice and divergence is calculated at each range gate from the lowest at 82 m to the highest at 2.3 km. An analysis of temporal and seasonal variations in the long-term averages of the atmospheric divergence and vertical air motion are presented.

THEORY

Computation of divergence (D) from a triangular network of RWP

- Line –integral method: Mean **D** in an area = Flux out of the area divided by the area
- Green's theorem in the plane: relationship between a line integral around a closed curve and a double integral over the plane region bounded by the curve:

$$D \equiv \frac{1}{A}\iint\left(\frac{\partial u}{dx}+\frac{\partial v}{dy}\right)dA = \frac{1}{A}\oint(u\,dy - v\,dx)$$

$$D = \frac{\oint(u\,dy - v\,dx)}{\frac{1}{2}\oint(x\,dy - y\,dx)}$$

- Path of integration along the curve is counterclockwise.

$$D = \frac{\sum(u_{ij}\Delta y_{ij} - v_{ij}\Delta x_{ij})}{\frac{1}{2}\sum(\Delta y_{ij}x_i - y_i\Delta x_{ij})}$$

Where i and j are two adjacent stations in counterclockwise direction, and:

$$u_{ij} = \frac{u_i + u_j}{2} \qquad v_{ij} = \frac{v_i + v_j}{2}$$

Computation of vertical velocity (w) through vertical integration of divergence:

$$w = -\int_0^z D(z)\,dz$$

- Integration between surface and first range gate assumes constant divergence equal to the value at the lowest range gate.
- z is height above ground level.

DATA & METHOD

Field Study

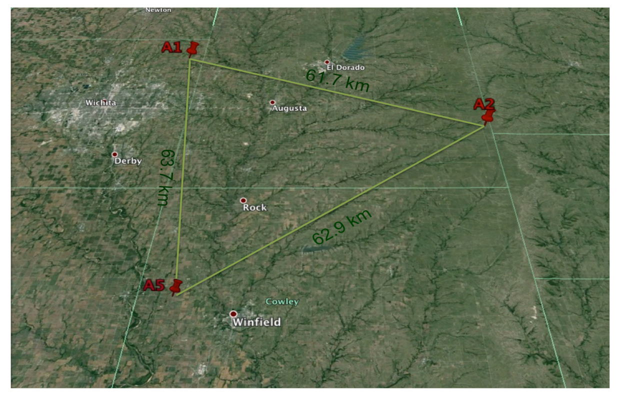
- **A**tmospheric **B**oundary **L**ayer **E**xperiments (**ABLE**) in south-central Kansas area within the **ARM SGP** site

Measurements

- Wind speed data from a triangular array of RWPs at SGP A1, A2, and A5 ancillary sites
- Data from 01-01-1999 to 03-31-2004
- Hourly averages of wind measurements

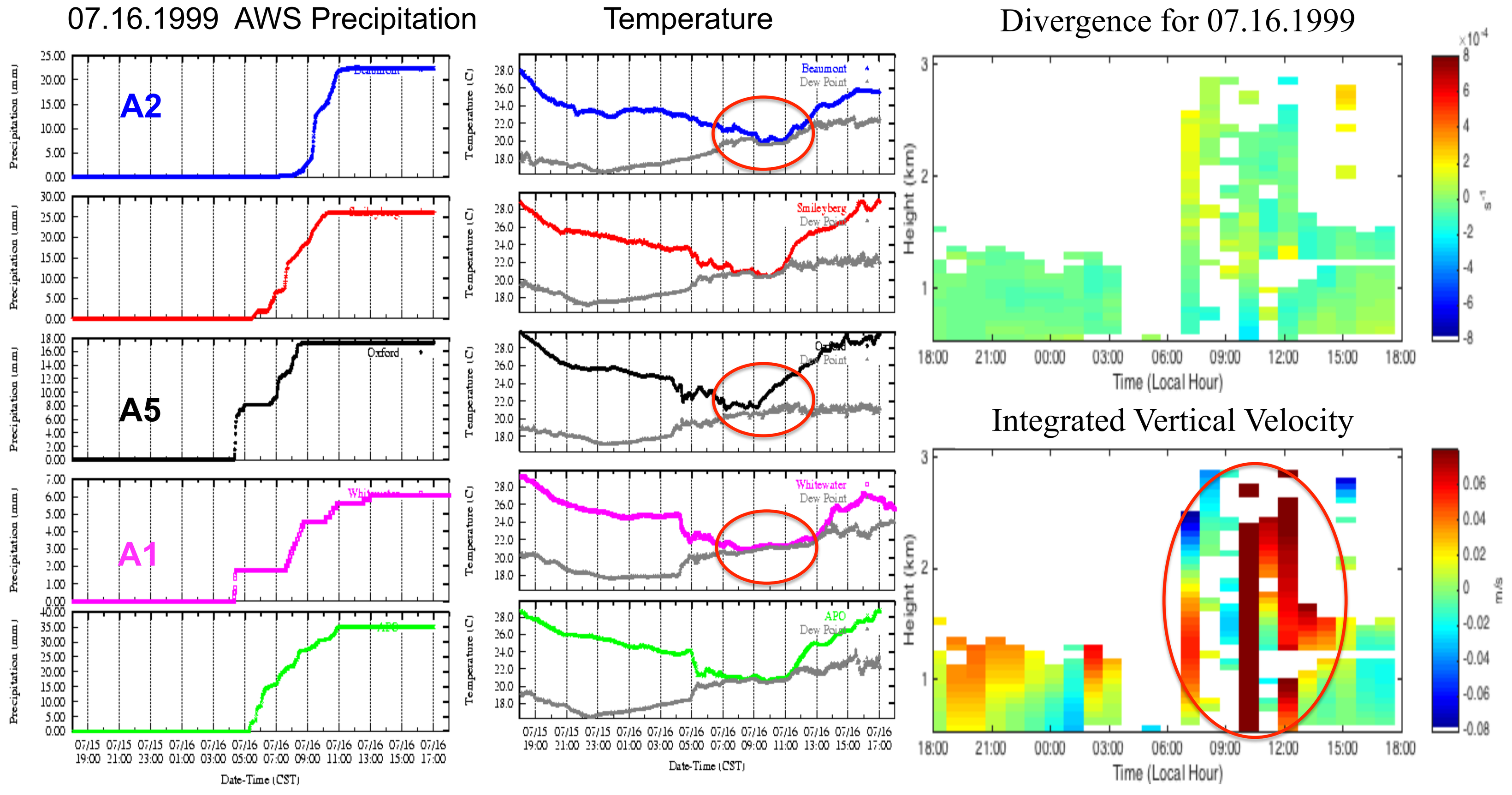
Method

- Wind speed threshold = ±25 m/s
- To account for height differences among RWP sites, geopotential height is used instead of height above ground



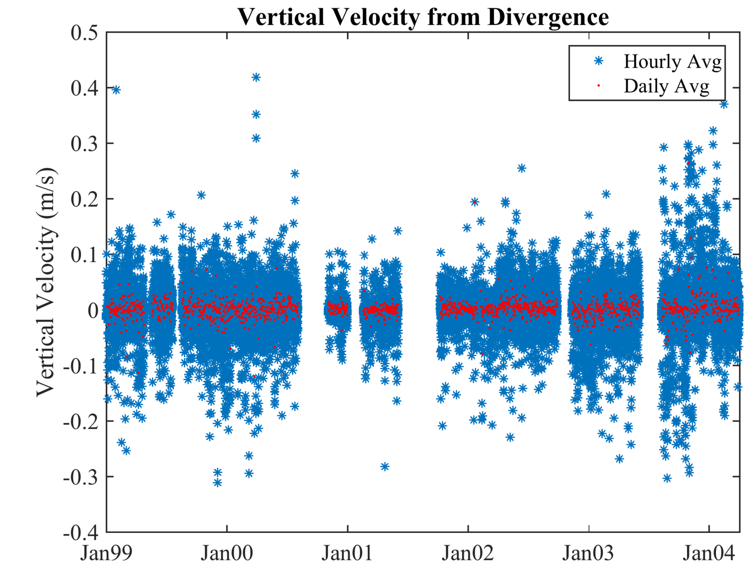
	A1 Whitewater	A2 Beaumont	A5 Oxford
Lat (deg)	37.841	37.273	37.627
Lon (deg)	-97.186	-97.095	-96.538
Alt (m)	416	360	478

RESULTS

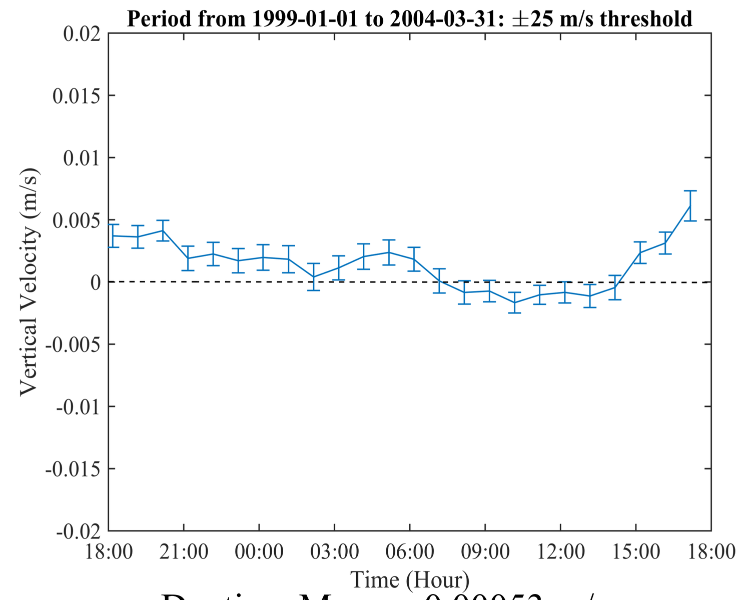


Credit: R. Coulter

- Divergence aloft is associated with rising air throughout the troposphere, which is associated with low pressure and convergence at the surface.
- Starting at the surface, the vertical velocity becomes more positive with height when there is surface convergence, reaches some maximum vertical velocity, and then becomes less positive with height again toward the divergence aloft.



Overall Mean = 0.00187 m/s
SEM = 0.00095 m/s

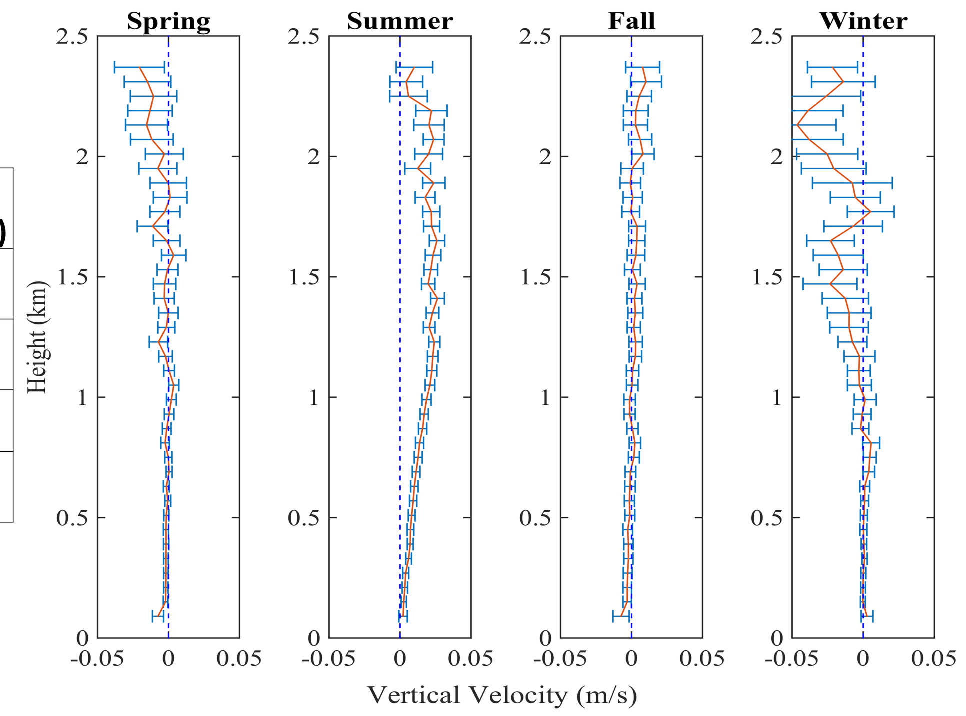


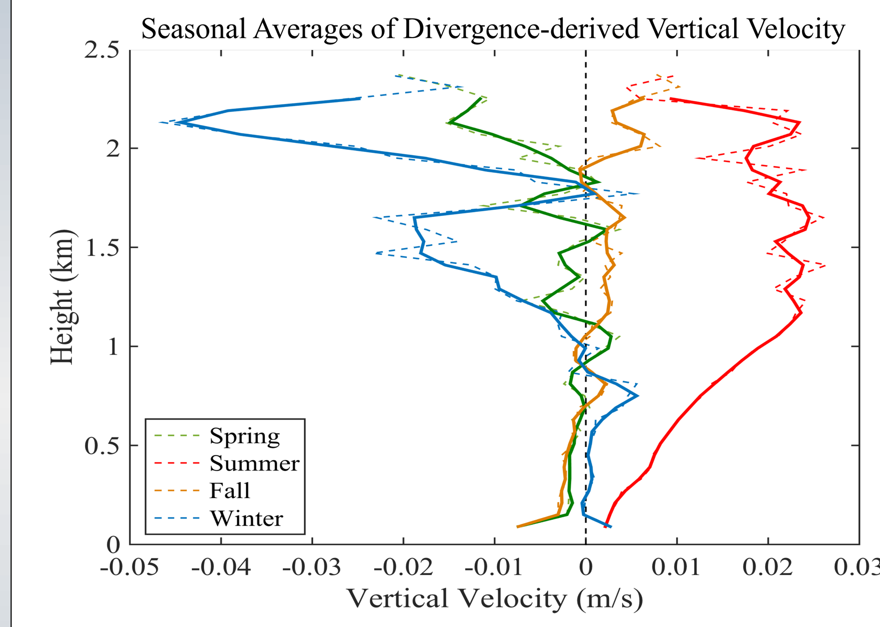
Daytime Mean = 0.00053 m/s
(10:00-17:00)
SEM = 0.00087 m/s

Larger night time mean : nocturnal jets or topography related nocturnal drainage winds?

Height profile of daytime (10:00 to 17:00) seasonal mean vertical velocity for the study period.

	Mean Vertical Velocity (m/s)	SEM (m/s)
Spring	-0.0036	0.0071
Summer	0.0155	0.0051
Fall	0.0012	0.0054
Winter	-0.009	0.0122





- Higher positive daytime vertical velocities for summer months
- Higher negative daytime vertical velocities for winter months

SUMMARY & DISCUSSIONS

- Climatology of vertical wind, one of the most important dynamical parameters of the atmosphere, is derived using 5 years of wind measurements from a triangular network of RWPs.
- Derived mean divergence and vertical velocity are consistent with the mesoscale situation in the area.
- Overall mean of the diurnal variation of vertical velocity from surface to 500 m height is 0.0018 m/s with a standard error of 0.00095 m/s, while the daytime mean is 0.00052 m/s with a standard error of 0.00087 m/s.
- Causes of generally larger night time mean vertical velocity need to be studied.
- Seasonal mean daytime (10:00 to 17:00) vertical winds suggest generally downward motion in Winter and upward motion in Summer during the day.
- Future work will be concentrated on the comparison of derived divergence and vertical velocities to that from climate models, as well as on the analysis of vertical velocities for clear sky and cloudy conditions.
- A different network of SGP RWPs (I8, I9, I10) with smaller distances and height variations between the sites will also be used to address local circulations smaller than the current ~60 km separation. This will also help evaluate the effect of the network size on reducing the uncertainty related to small misalignments.

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