Long-Term Vertical Velocity Statistics Derived from Doppler Lidar in the Continental Convective Boundary Layer

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Motivation

- Distributions of vertical velocity (w) are needed to understand both PBL turbulence and boundary-layer clouds
- Most studies of w statistics are derived from short-term aircraft observations or tower based studies
  - BAO (300 m)
  - Cabaw (213 m)
- Long-term measurements of w statistics are lacking, but are needed for evaluating model results and developing new parameterizations
  - ARM LASSO (LES ARM Symbiotic Simulation and Observation) project
- Data collected by Department of Energy's Atmospheric Radiation Measurement (ARM) Climate Research Facility provide a unique opportunity to address this need.

Outline

- Data description
- Composites of w stats
- Sorting the results
- Conclusions

ARM Doppler Lidars and Analysis Criteria

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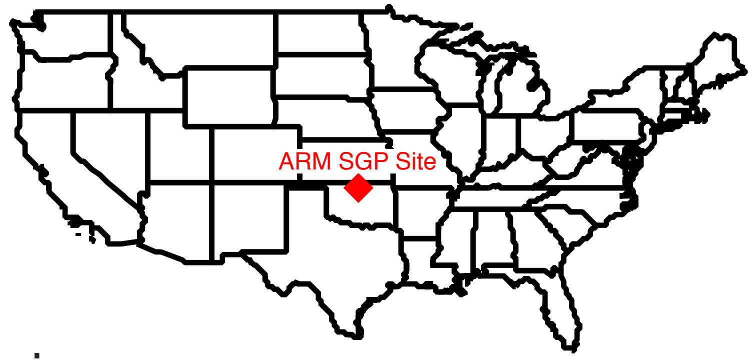
- Halo-Photonics DL Deployed at ARM fixed sites and AMF
  - Near-IR (1.5 μm)
  - Range is typically less than 2 km for clear-air retrievals



- Value Added Product (VAP) has been developed that includes wind profiles and key statistics: variance, skewness, and kurtosis
- Utilize ARM meteorological and flux data, wind profiles from 915 MHz radar wind profilers

- Data selection criteria
  - Require SNR to be ≥ 0.03 (more stringent criteria used for higher order stats)
  - Define z_i using a threshold of variance (0.04—based on Tucker et al. 2009)
  - $z_i > 0$, $w_* > 0$ (implies positive surface heat flux)
  - Cloud Fraction < 0.001

Representative Case: 18 July 2015

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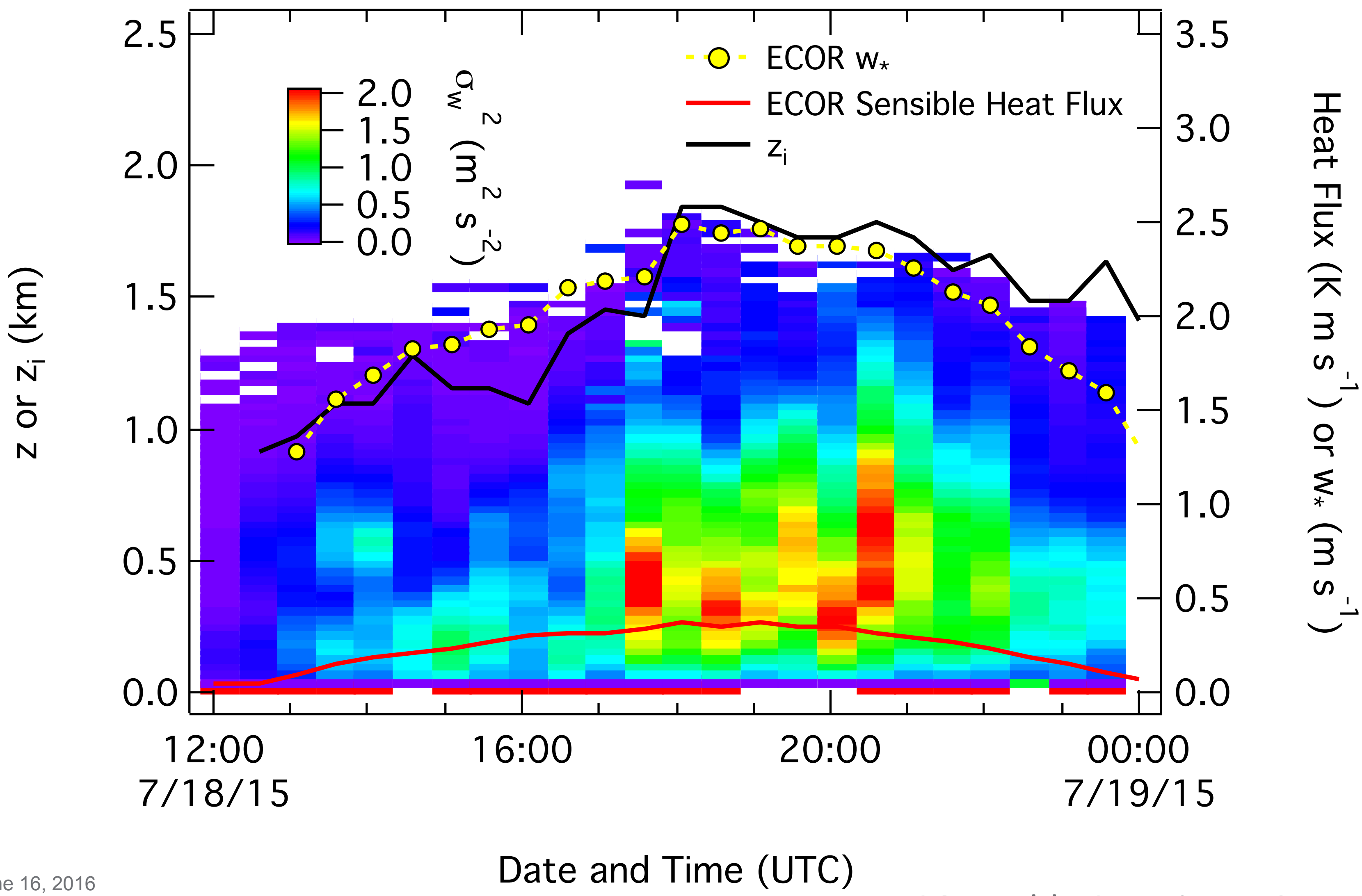
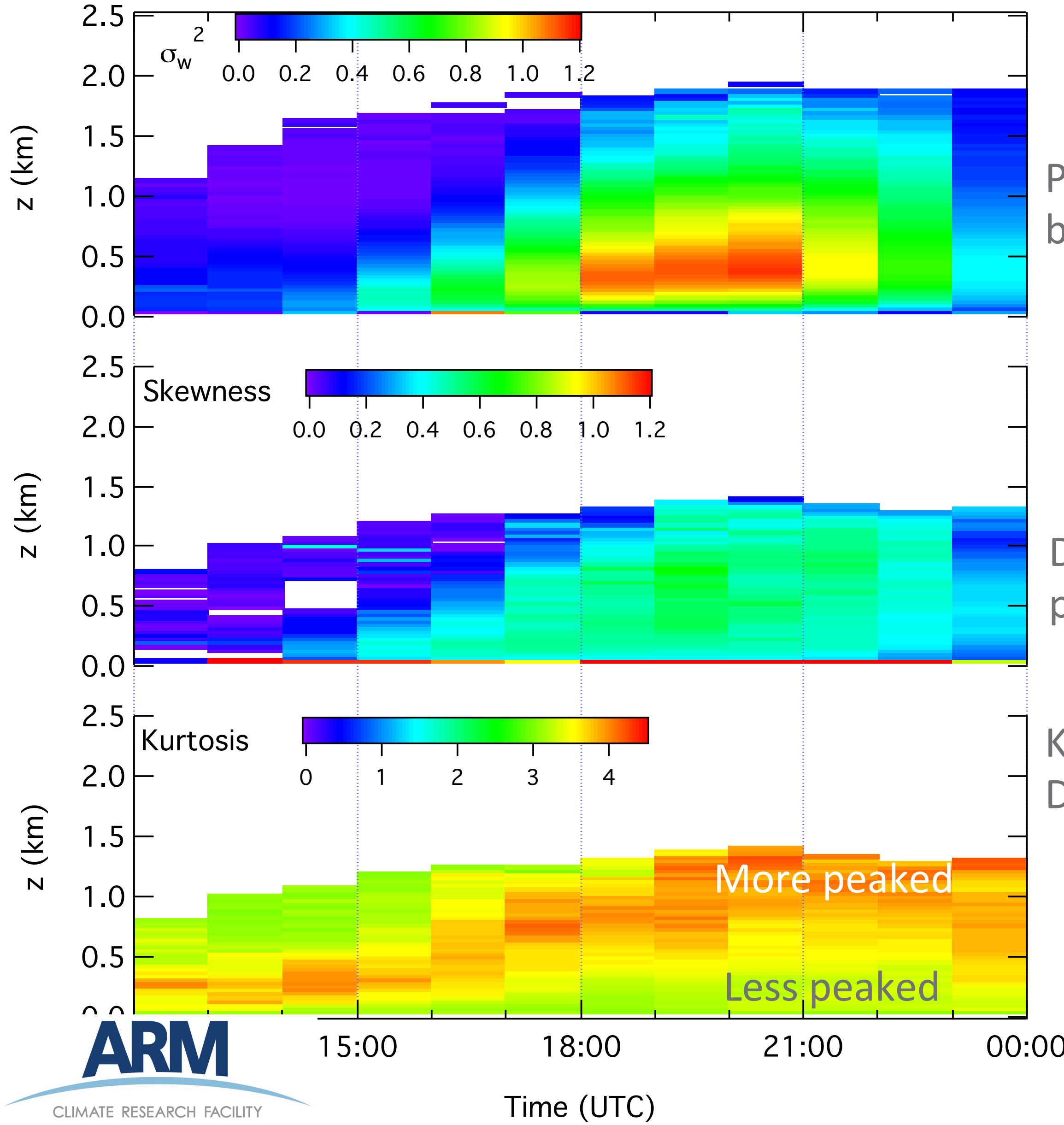


ECOR=Eddy Covariance System

Composite Statistics



Peak value smeared by averaging

Daytimes values positively skewed

Kurtosis of Gaussian Distribution = 3

Sensitivity of Statistics to Parameters

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- The w statistics can be sorted by many different ways—think of factors that could influence the PBL turbulence
  - Time of day
  - Wind direction
  - Season
  - Surface shear stress/friction velocity (u*)
  - Wind Shear at PBL top
  - Static stability
- Use Kolomogorov-Smirnov test to determine if differences are statistically significant
  - Look to see if values could be from the same parent distribution

Change in Variance Profile with Time

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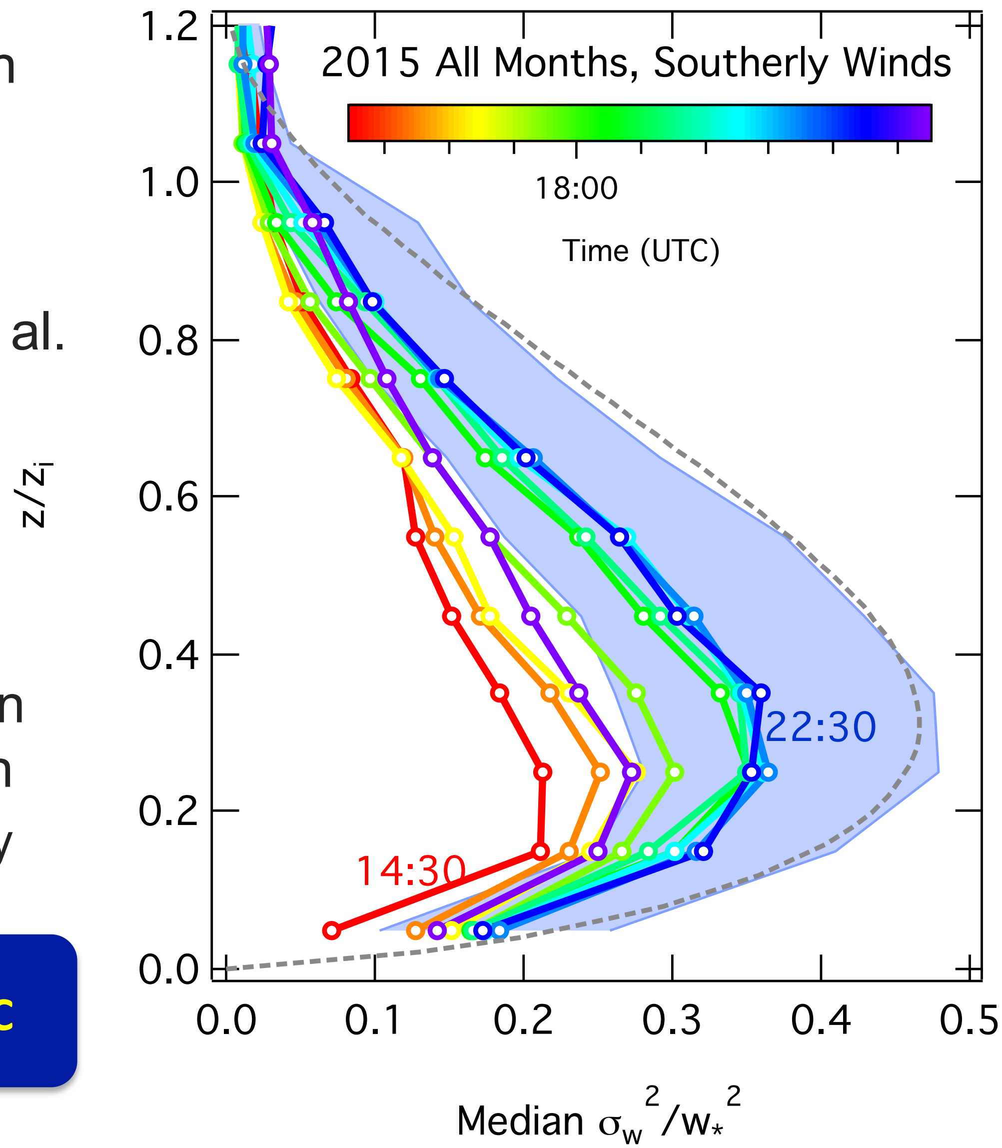
- All values of σ_w^2 have been normalized by w_*
- Values tend to be smaller than short-term results presented by Lenschow et al. (2012):

$$\frac{\sigma_w^2}{w_*^2} = 1.8\left(\frac{z}{z_i}\right)^{2/3}\left(1-0.8\frac{z}{z_i}\right)^2$$

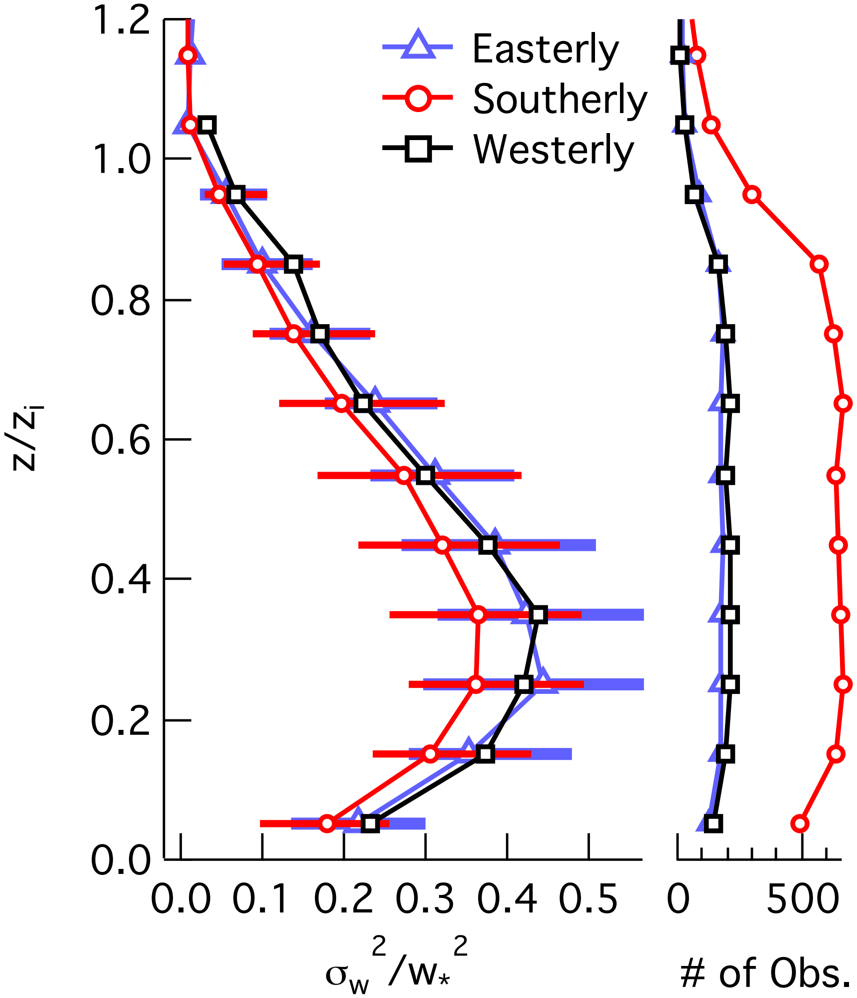
- Normalization works best in late-morning and afternoon
  - PBL approximately steady state

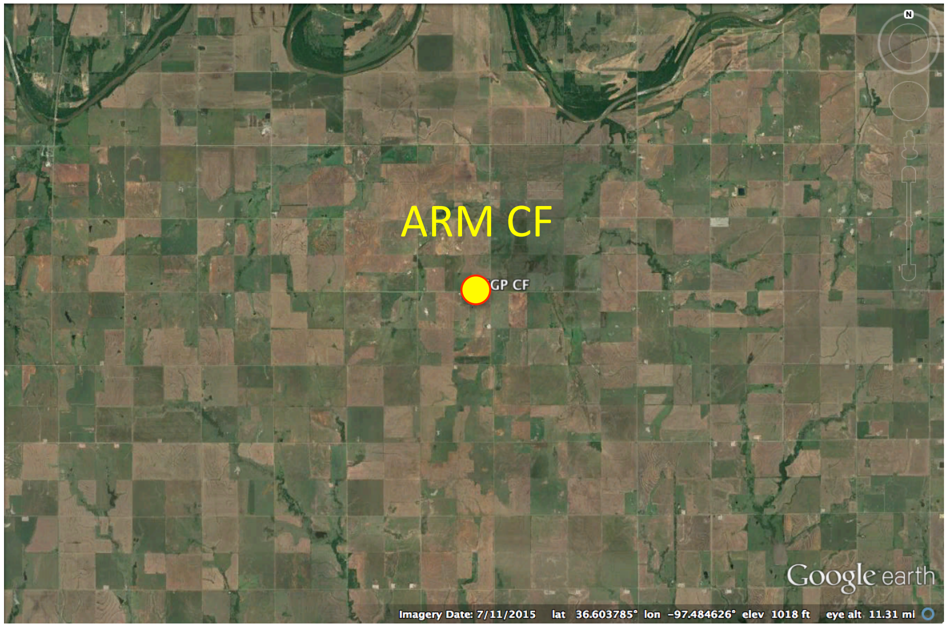
Limit analysis to 17 to 23 UTC



Sensitivity of σ_w^2/w_*^2 to Wind Direction

- Differences in land use and surface roughness associated with wind direction could lead to differences in velocity statistics

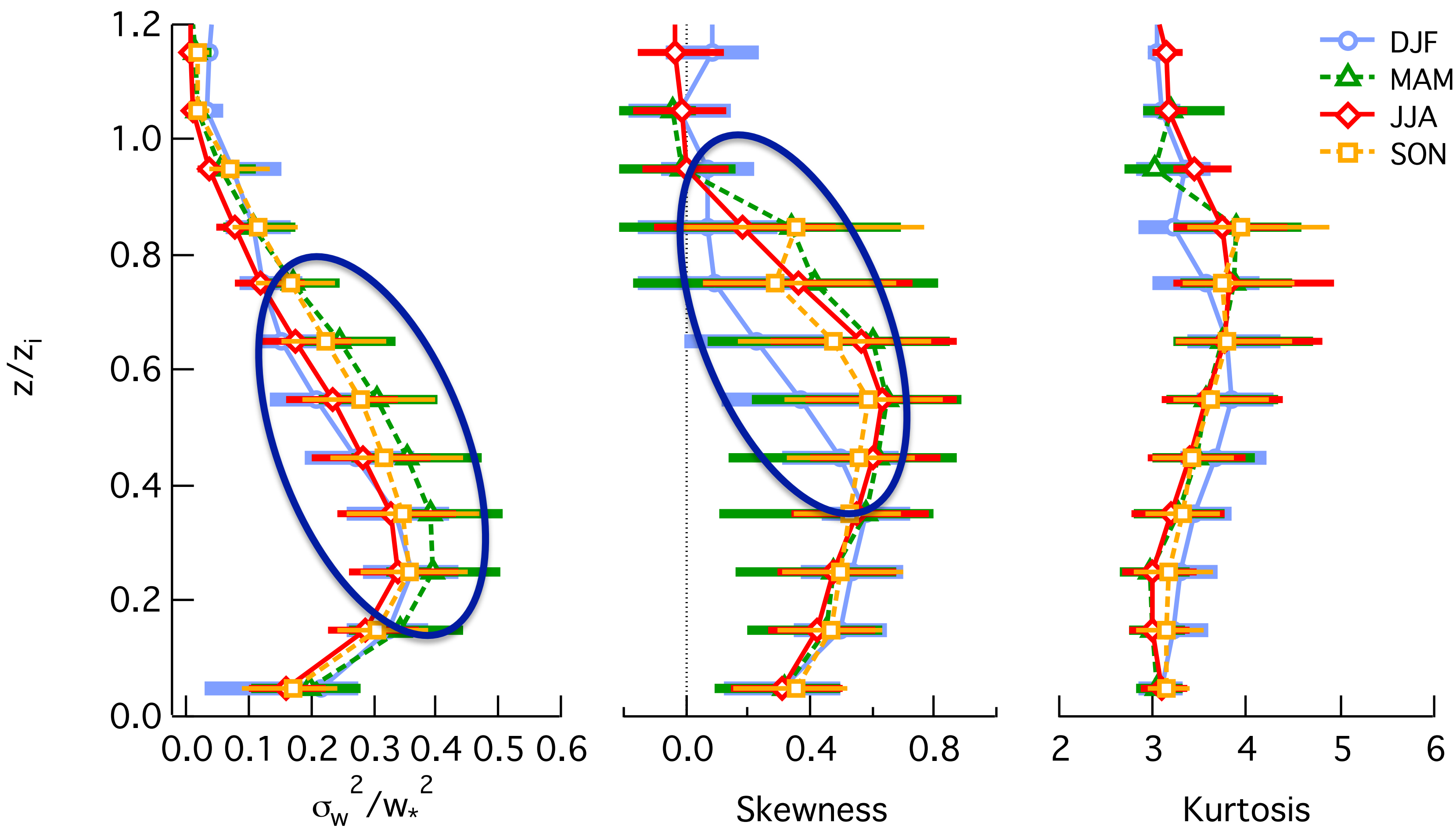




Limit analysis to periods with southerly winds

Error bars: 75th and 25th percentiles

Dependence on Season



$\sigma_w{}^2/w_*{}^2$ changes with season, differences in surface heterogeneity?
Skewness larger in PLB top during warm seasons

Dependence on u_*

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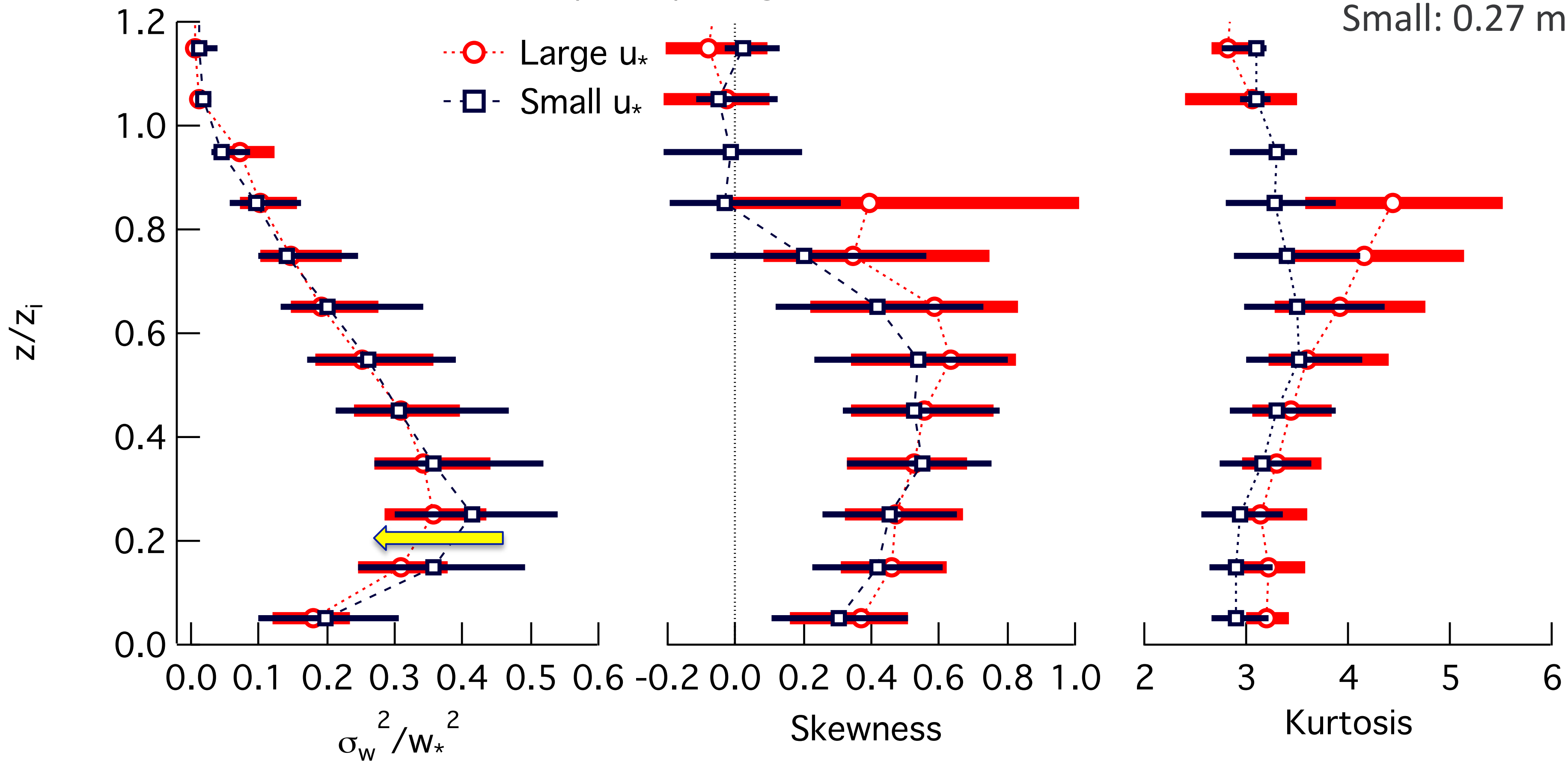
- Values of u_* from surface flux measurements were sorted to determine critical values
  - u* in Lenschow et al. (2012) ranged from 0.16 to 0.52 ms^{-1}

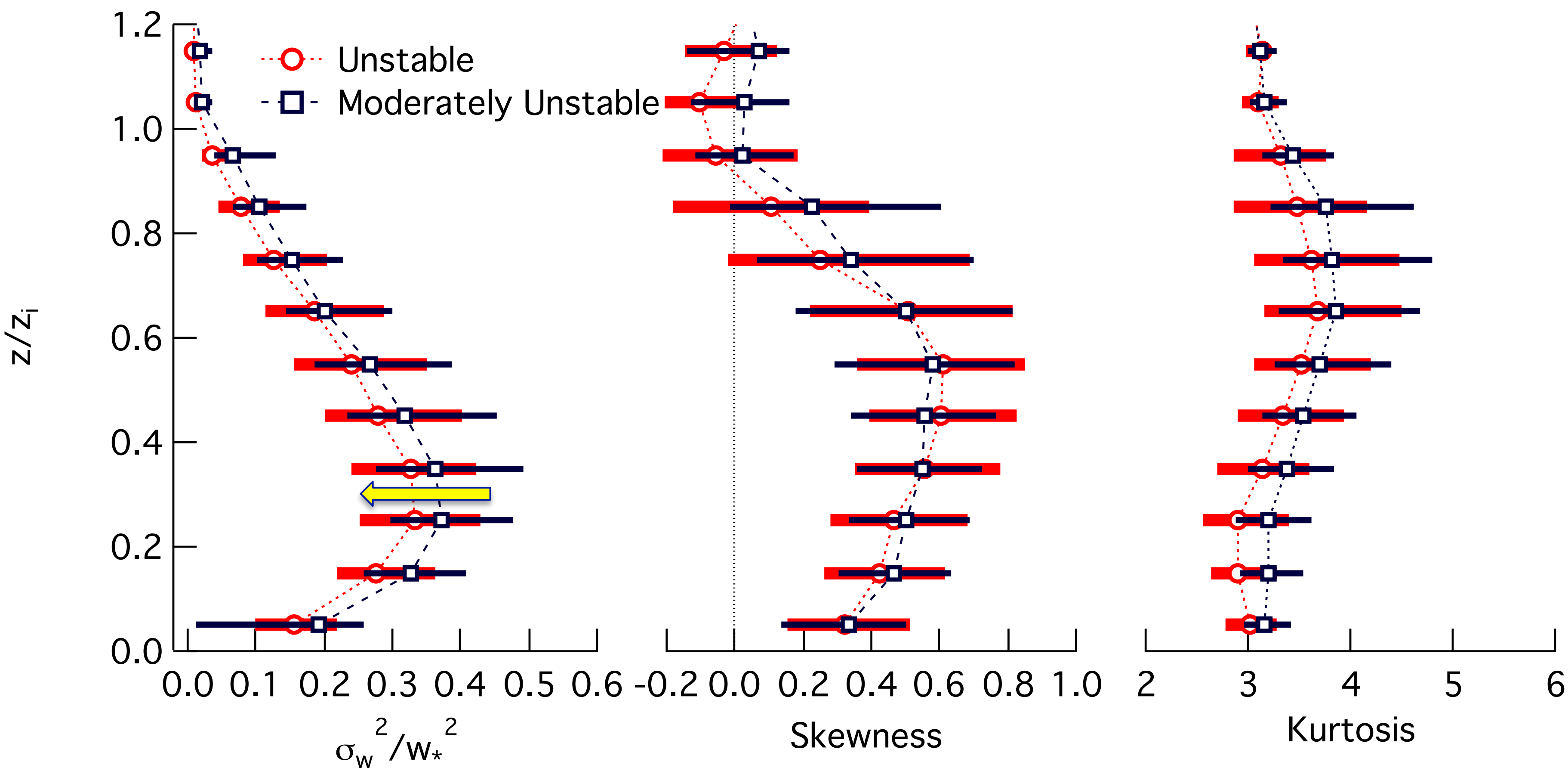
Large: 0.59 ms^{-1}
Small: 0.27 ms^{-1}



Large values of u* lead to small values of σ_w^2/w_*^2 and kurtosis

Dependence on Stability

- Stability defined using $-z_i/L$
  - Values greater than 30 are unstable, less than 30 moderately unstable



Unstable cases have smaller values of σ_w^2/w^* and kurtosis

Dependence on Wind Shear Across the Boundary-Layer Top

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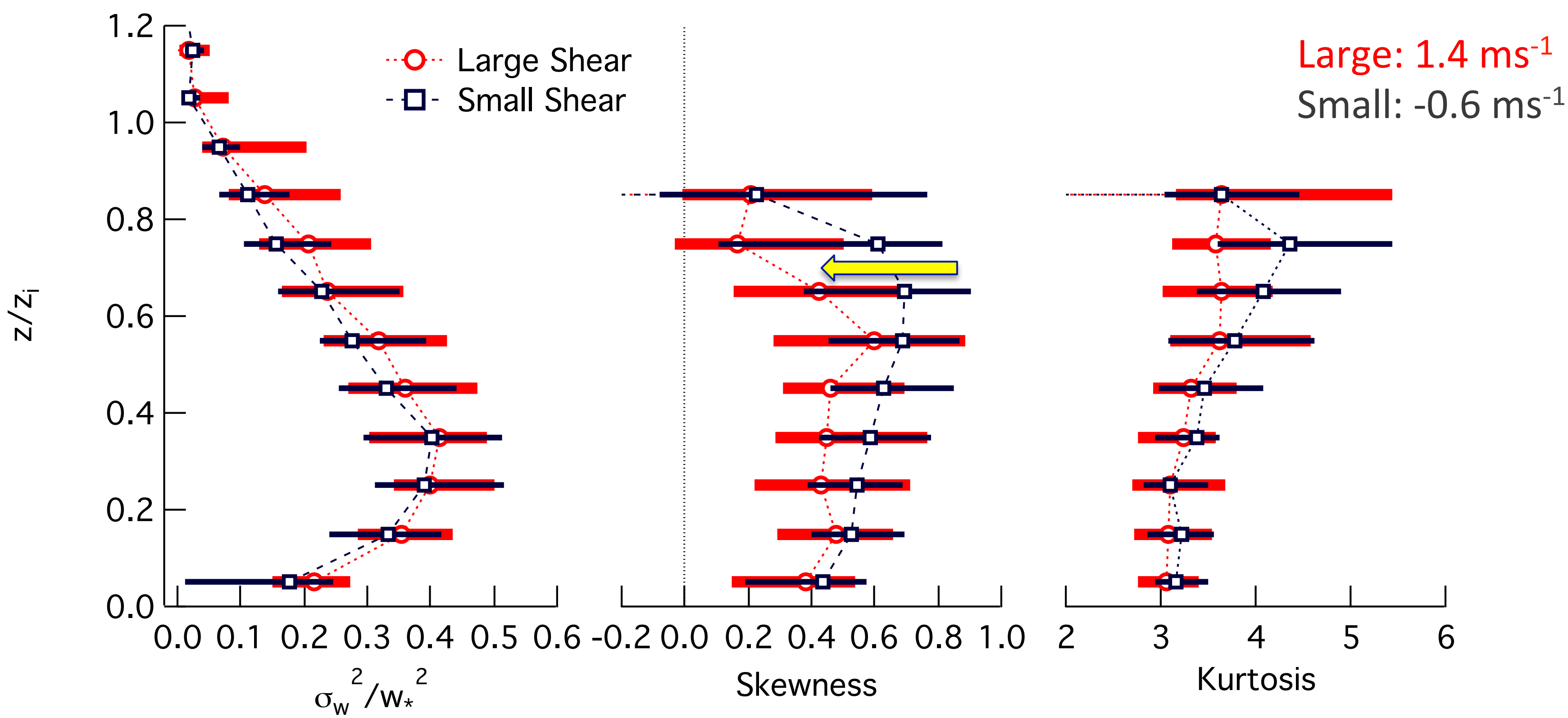
- Wind shear determined from radar wind profiler
  - Based on wind speed differences between z/z_i of 1.1 and 0.9



Cases with large amounts of shear are less skewed over much of the BL

Conclusions

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- Data from ARM Doppler lidars provide a unique opportunity to look at long-term vertical velocity statistics
- Scaling with w* works best for cases when BL is quasi-stationary
- There as systematic differences in the σ_w^2/w_*^2, skewness, and kurtosis associated with differences is:
  - Season
  - Surface stress: smaller values of u* lead to large values of σ_w^2/w_*^2
  - Stability: Moderately unstable conditions lead to larger values of σ_w^2/w_*^2 and kurtosis
  - Wind Shear across the BL top: small values of shear lead to larger values of skewness
  - Future efforts will extend work to stable conditions

Variance largest in spring; Skewness larger in warmer seasons

Less intense mixing at surface leads to larger variance

Less intense mixing at boundary-layer top leads to larger skewness

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ARM CLIMATE RESEARCH FACILITY

ASR Atmospheric System Research

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