NWRA

NorthWest Research Associates, Inc.

Redmond, WA

Analysis of the Short-Term Variability of Crosswind Profiles

Workshop on Short-Term Weather Forecasting for Probabilistic Wake-Vortex Prediction

WakeNet3-Europe
DLR Oberpfaffenhofen, Germany

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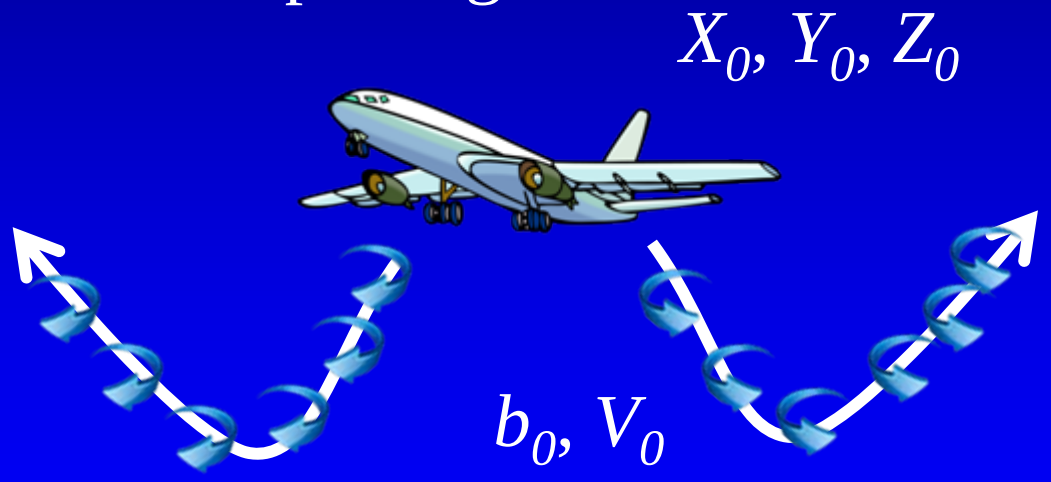
Background

- We are developing a new probabilistic fast-time wake model
  - Examining uncertainties of the model inputs
  - Given “best” model inputs, we are also examining errors in the simulation results of several deterministic fast-time wake models
- Meteorological conditions significantly affect lifetimes, trajectories, and circulation intensity of wake vortices

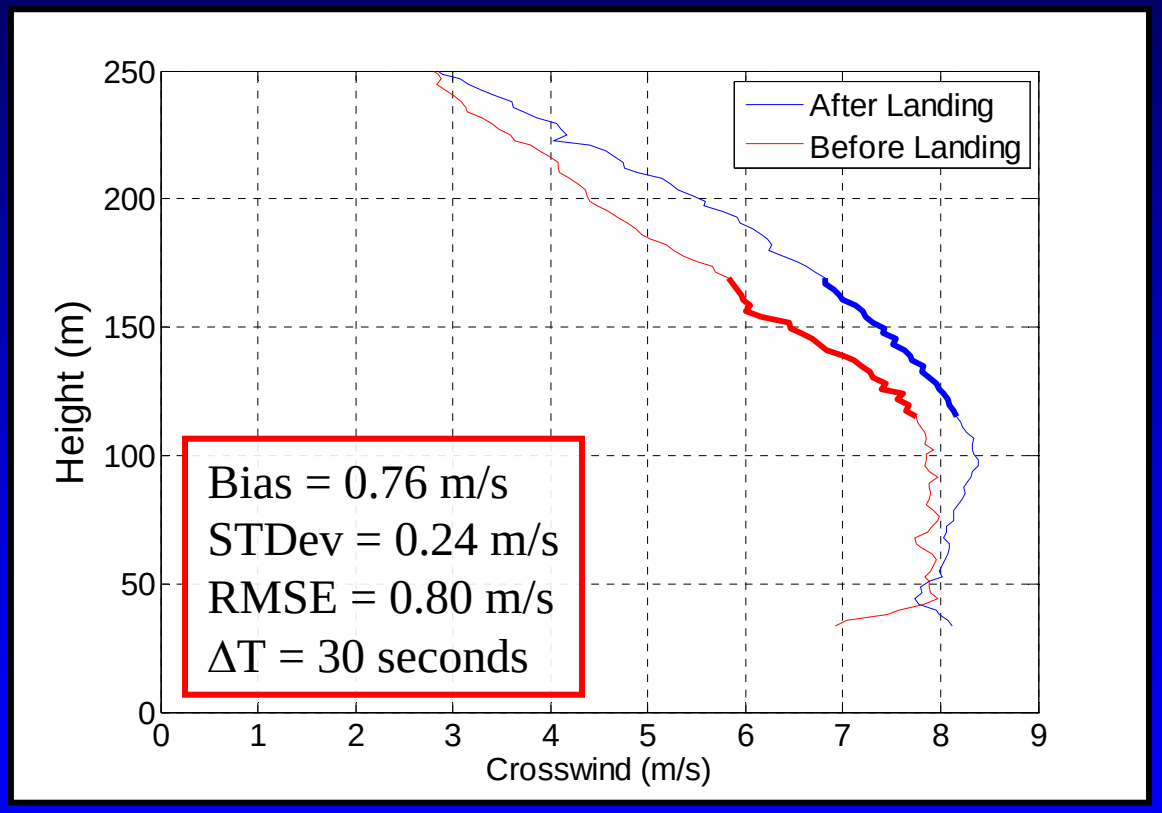
Estimating Uncertainties of Model Inputs

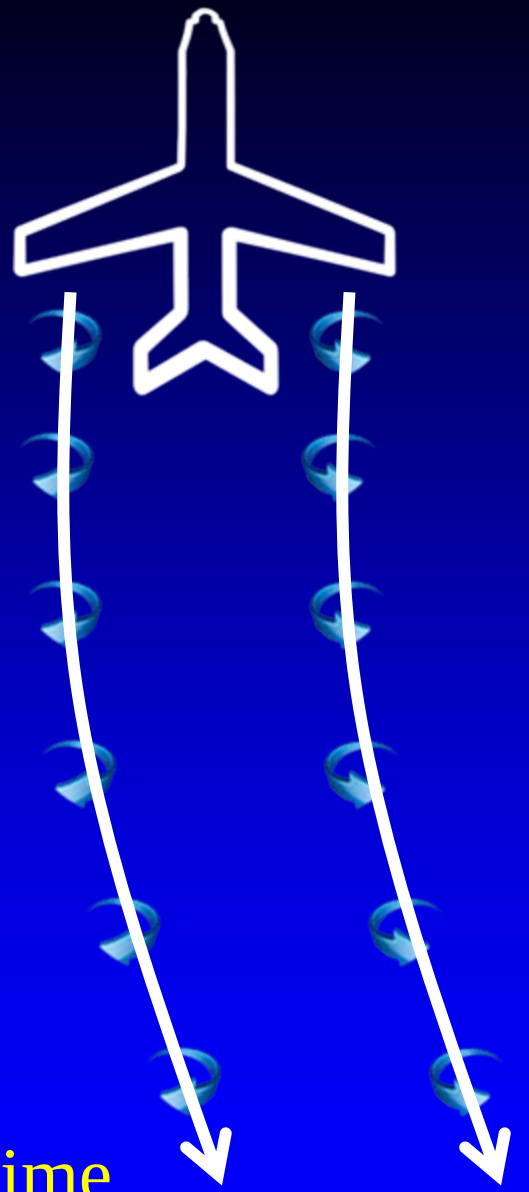
EDR (x,y,z,t)
Pot. Temp. (x,y,z,t)
Crosswind (x,y,z,t)
Headwind (x,y,z,t)
Vert. Velocity (x,y,z,t)
Air density (x,y,z,t)

Aircraft weight
Air speed (and acceleration)
Glide Slope Angle



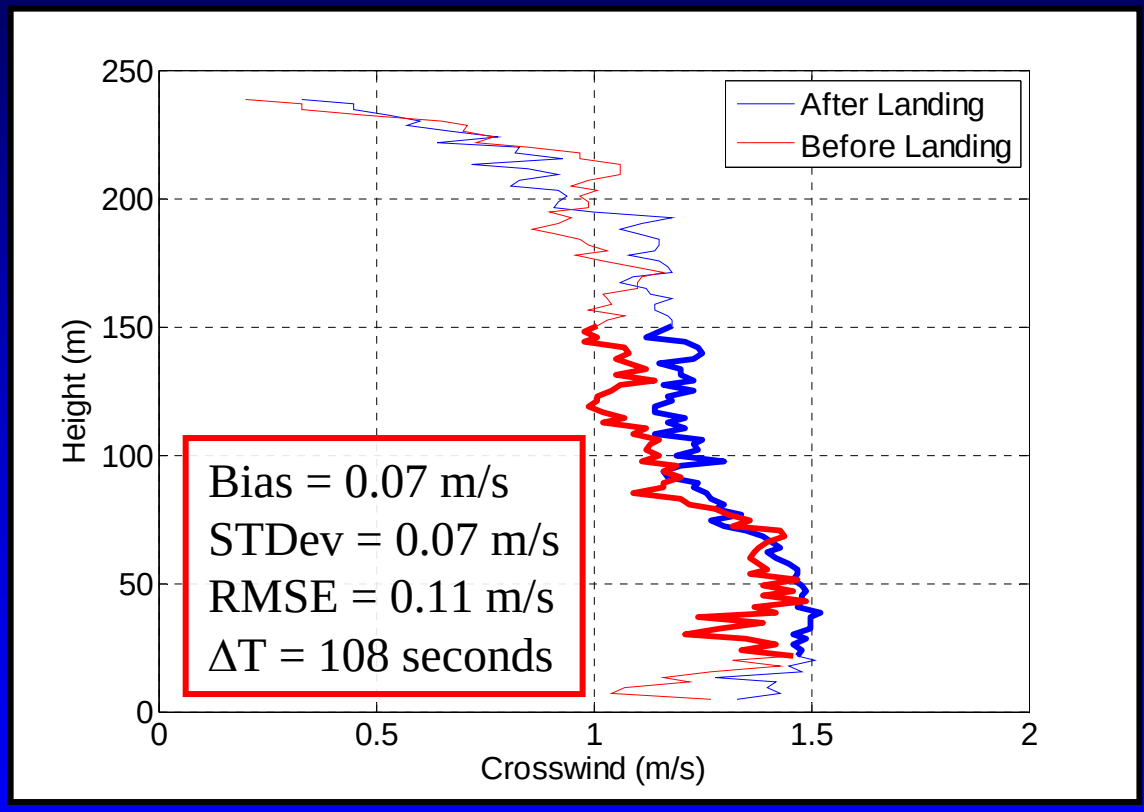
Importance of Short-term Variability of Crosswind

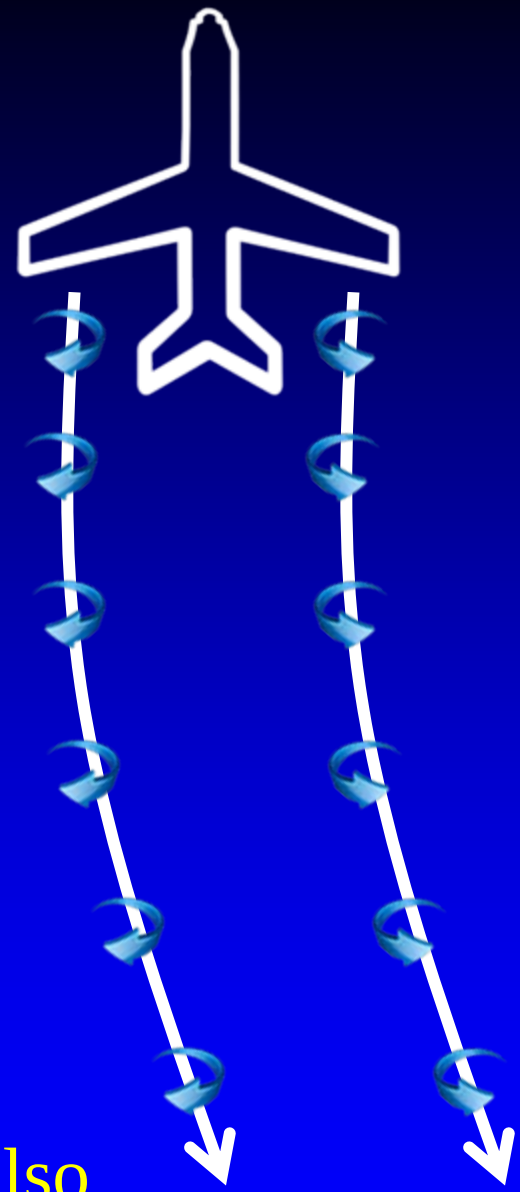




Fluctuations in crosswinds as a function of time affect the vortex trajectories

Importance of Short-term Variability of Crosswind





Temporal fluctuations in crosswinds may also affect the lidar-measured vortex lifetimes

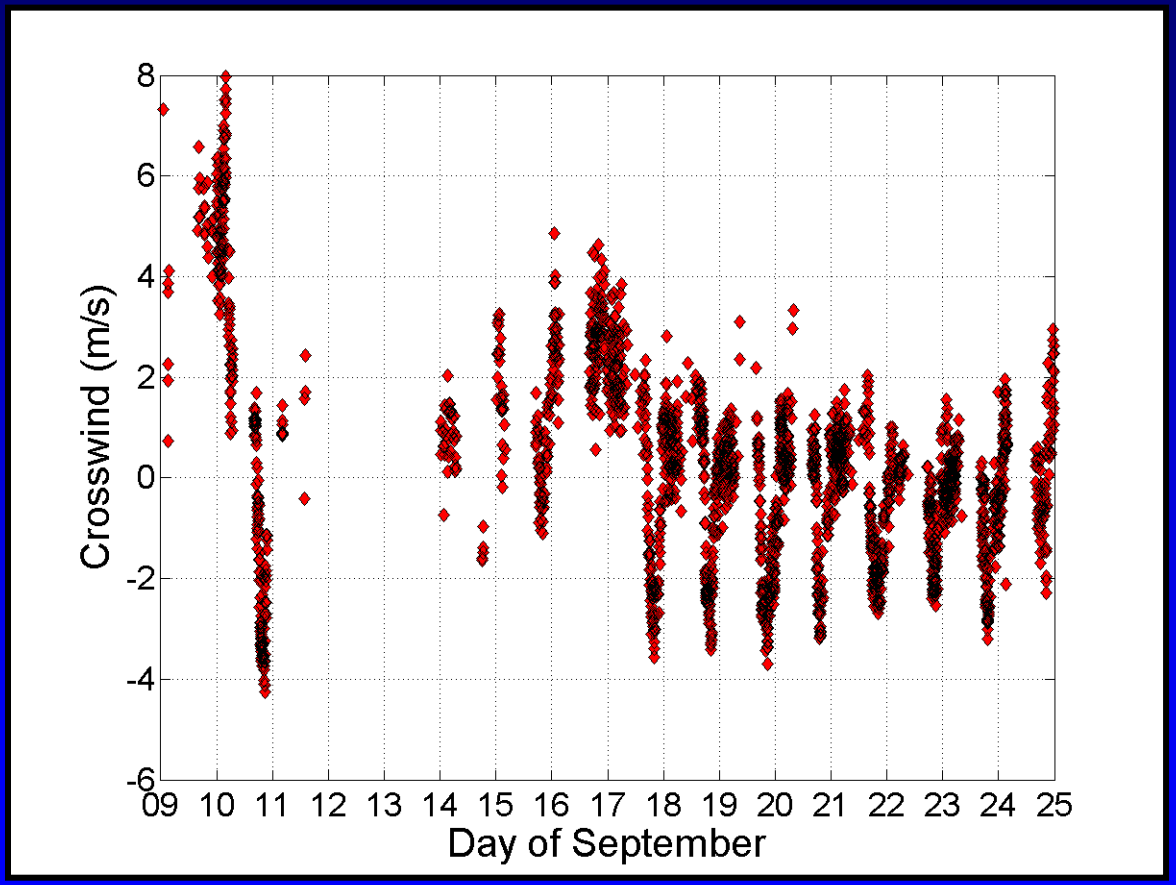
Short-term Fluctuations in Wind Speed Along the Lidar Line of Sight

1. To obtain the statistical properties of the fluctuations, two data set of lidar-measured line of sight wind-speed were analyzed
2. The wind-speed fluctuations were separated into the long(er) term residuals of a regression model (bias) and the temporal variability in the wind profile (variance)
3. The statistical analysis revealed that the observed wind speed fluctuations over the vortex lifetime are similar at two different sites and is correlated with the time of day

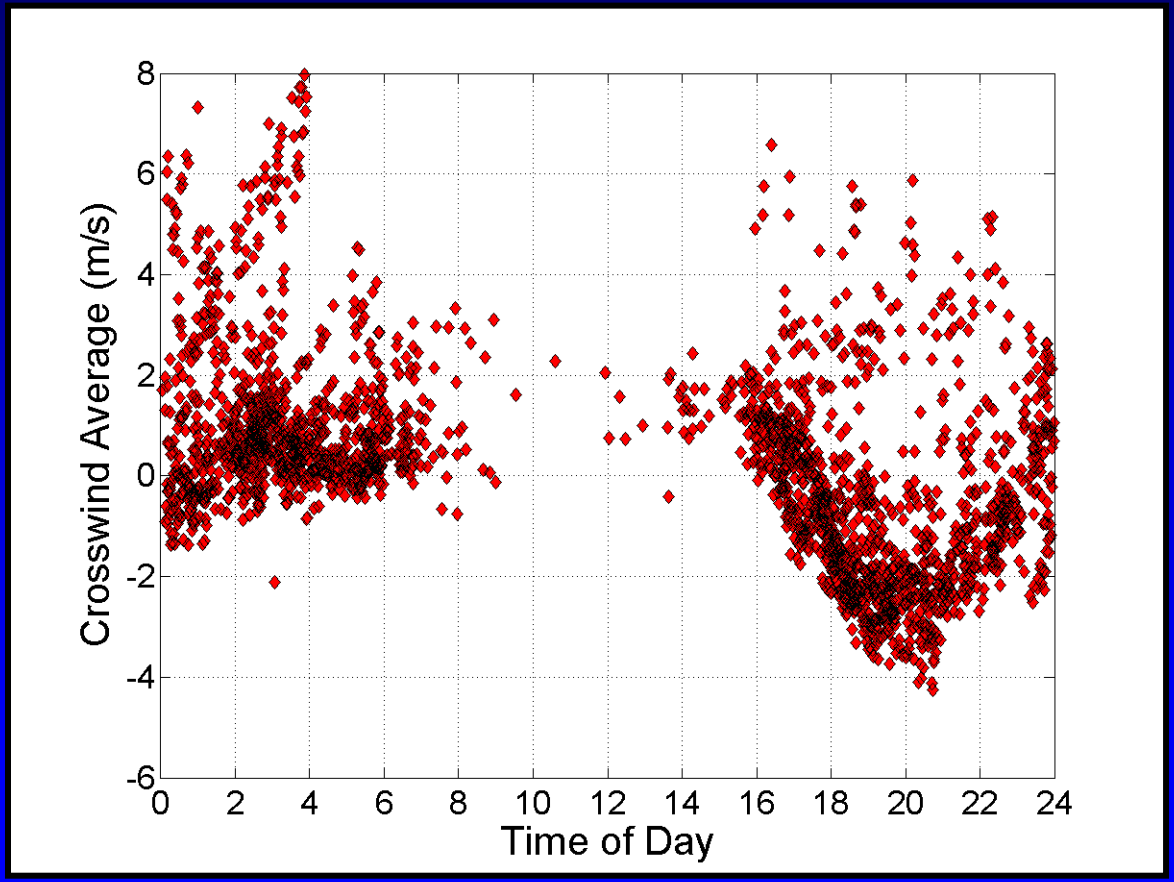
SFO 2001 OGE

- 2155 landings
- 25 different aircraft types
- Glide slope altitude approximately 150 m
- LMCT pulsed-lidar
- Data set covers over 2 weeks in Sept., 2001
- FAA provided the data for this analysis

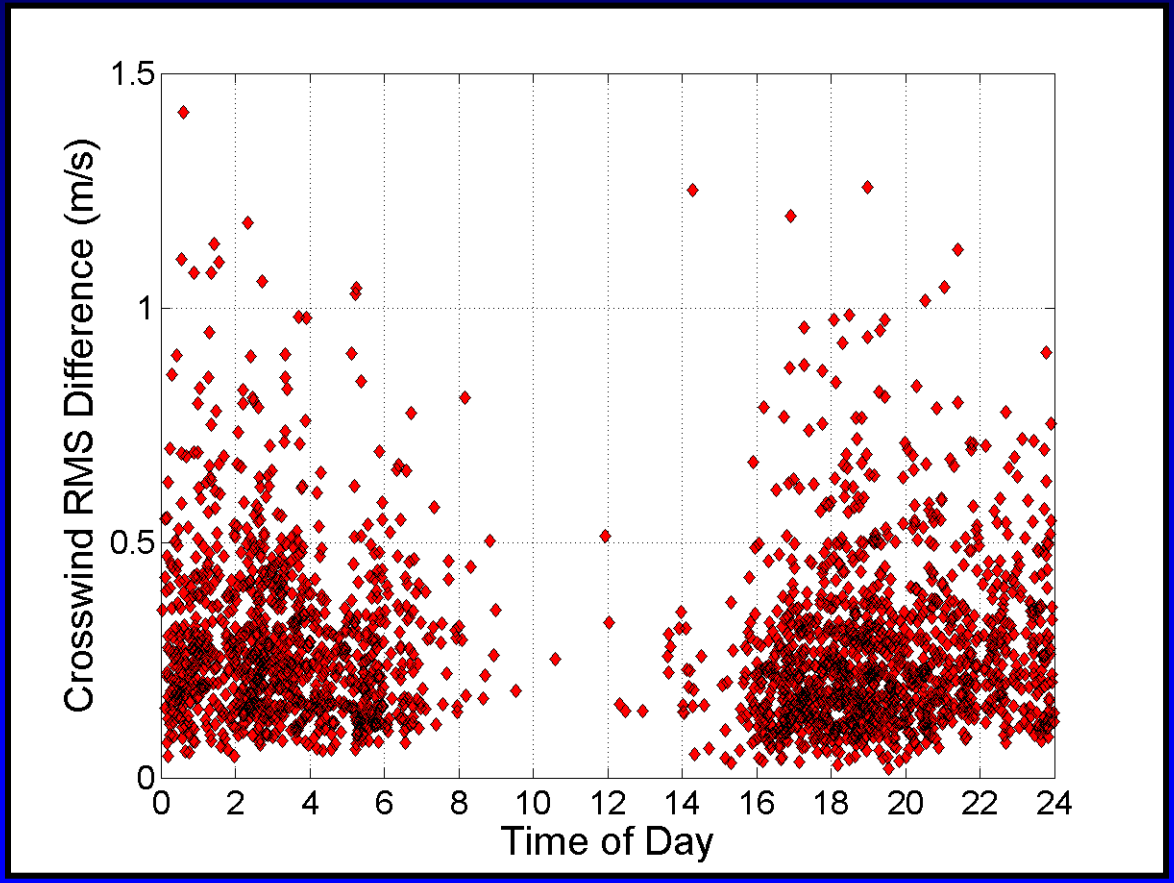
SFO 2001 OGE Average Crosswind Day of Year



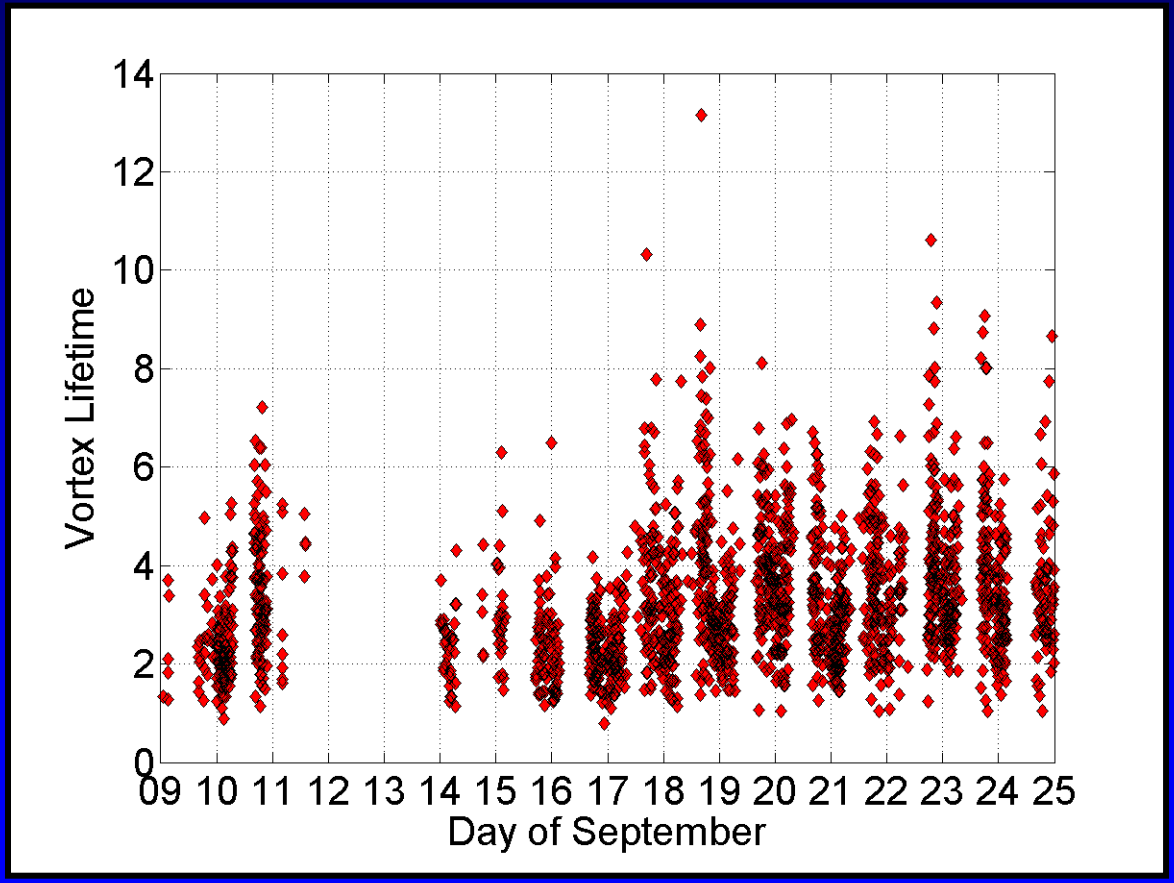
SFO 2001 OGE Average Crosswind Time of Day (GMT)



SFO 2001 OGE RMS Difference CW Time of Day (GMT)



SFO 2001 OGE Measured Lifetimes Day of Year



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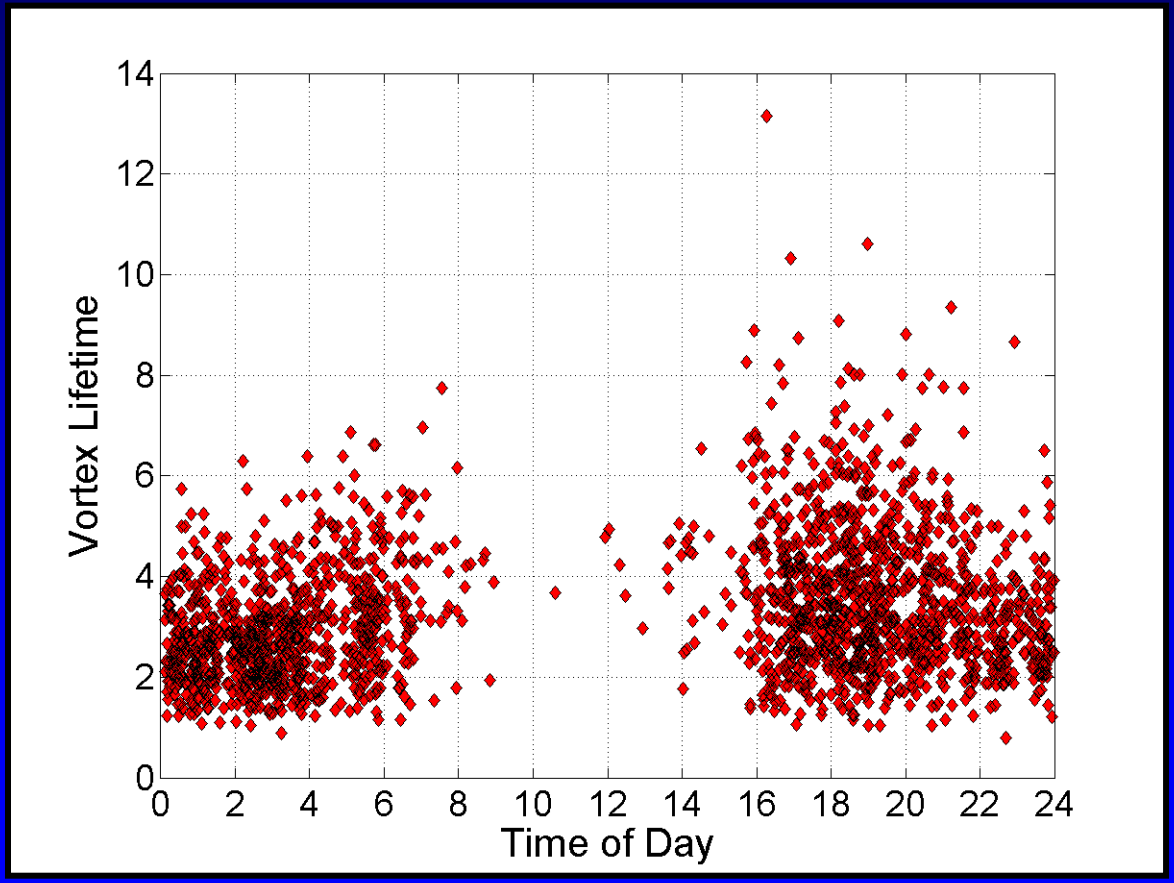
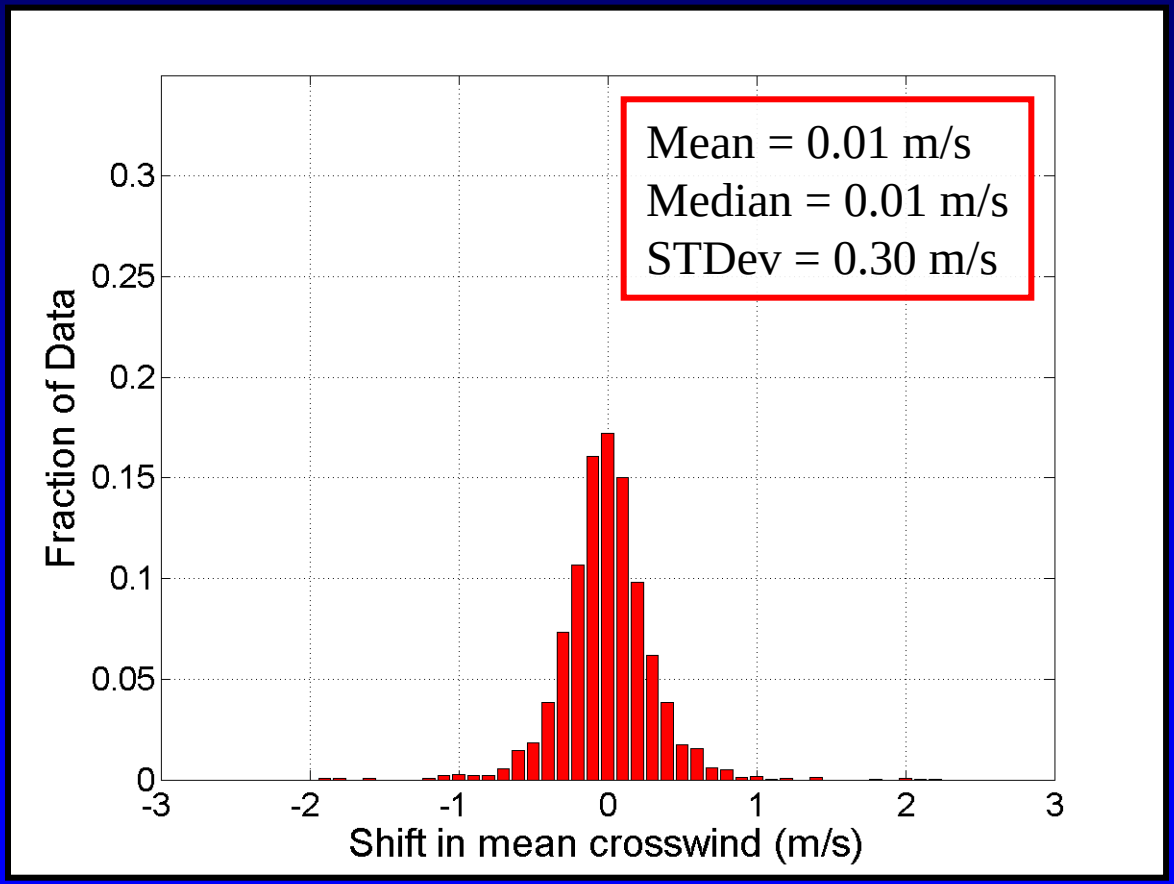


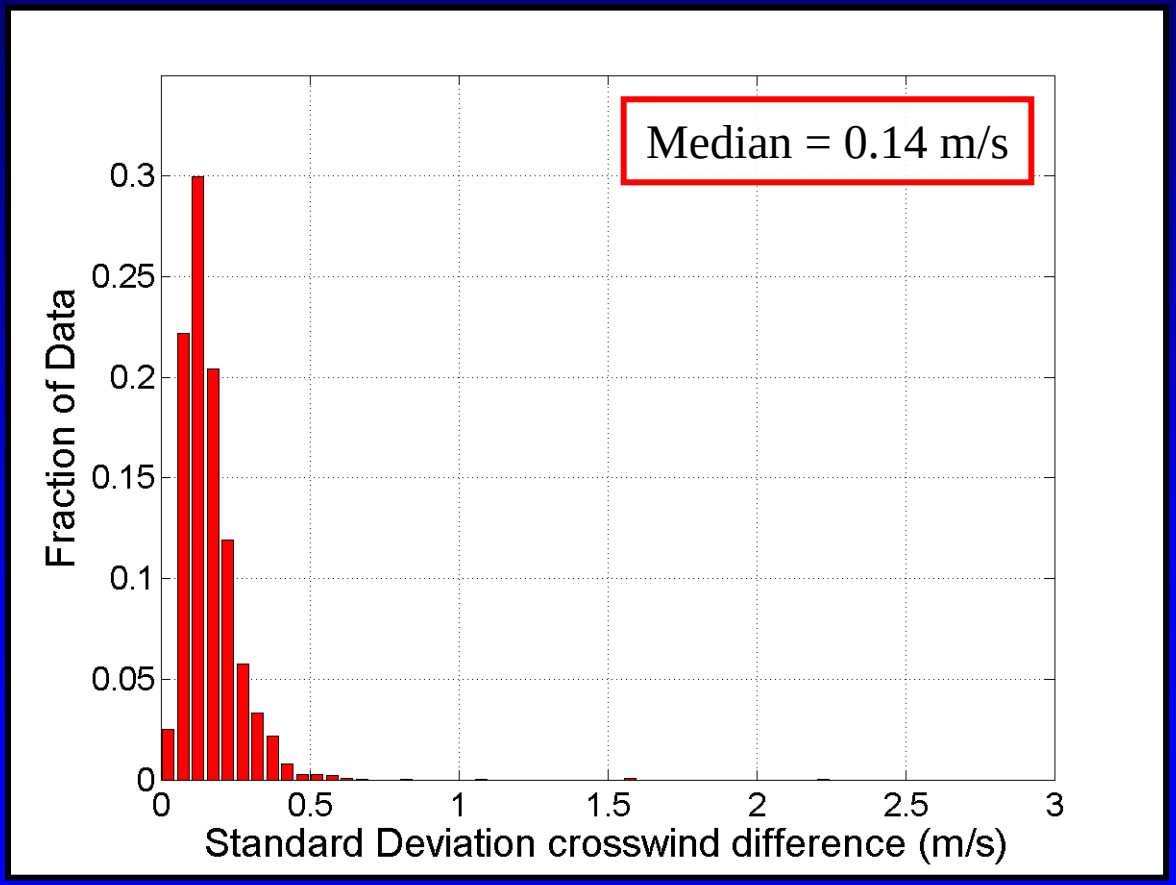
SFO 2001 OGE Bias

(mean shift in wind over vortex lifetime)



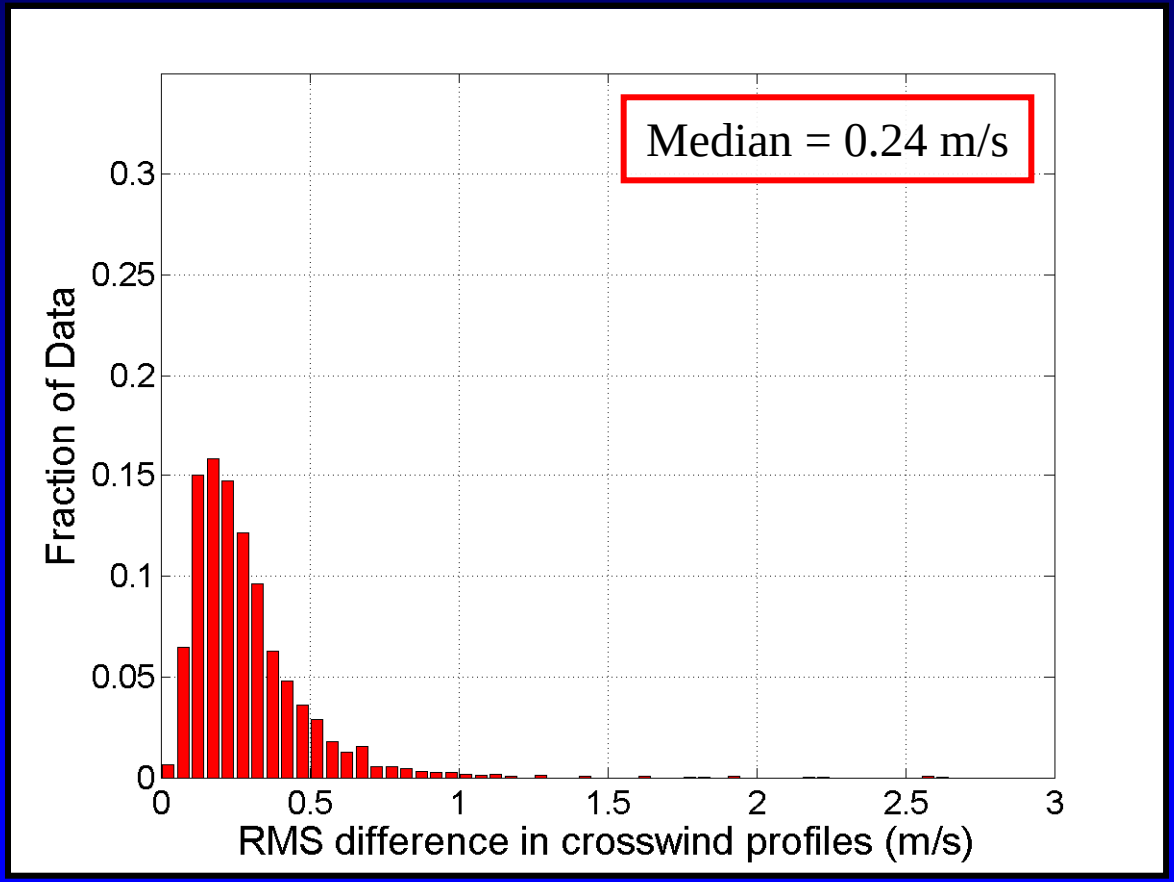
SFO 2001 OGE Standard Deviation

(difference in wind profiles over vortex lifetime)



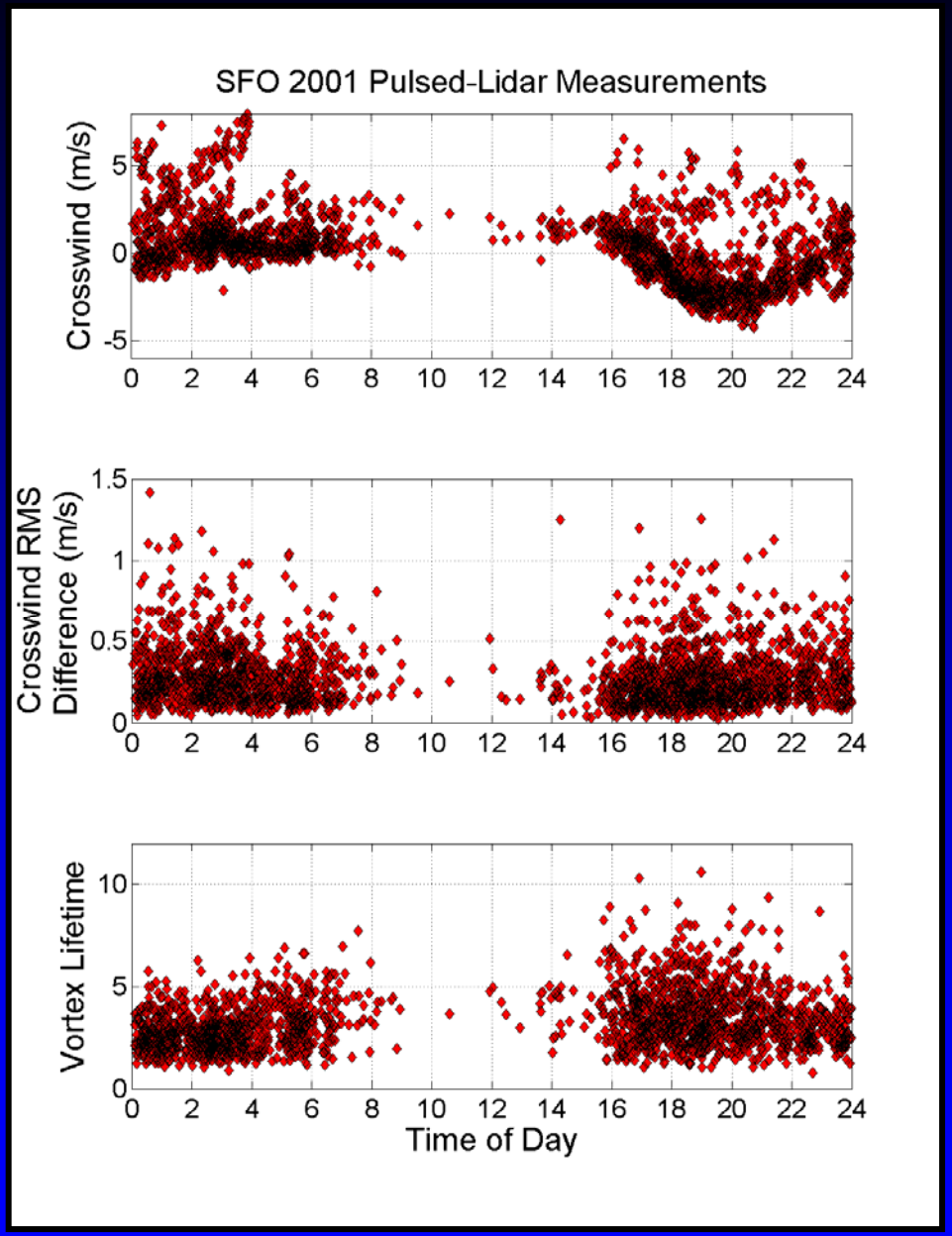
SFO 2001 OGE RMS Difference

(RMS difference in wind profiles over vortex lifetime)



Analysis of the line of sight lidar-measured wind shows

1. Both the lidar-measured line of sight wind speed and its short-term variability are correlated with time of day
2. Lidar-measured vortex lifetimes are also correlated with time of day
3. Larger short-term variability in the lidar line of sight wind speed may be correlated with shorter observed lifetimes.

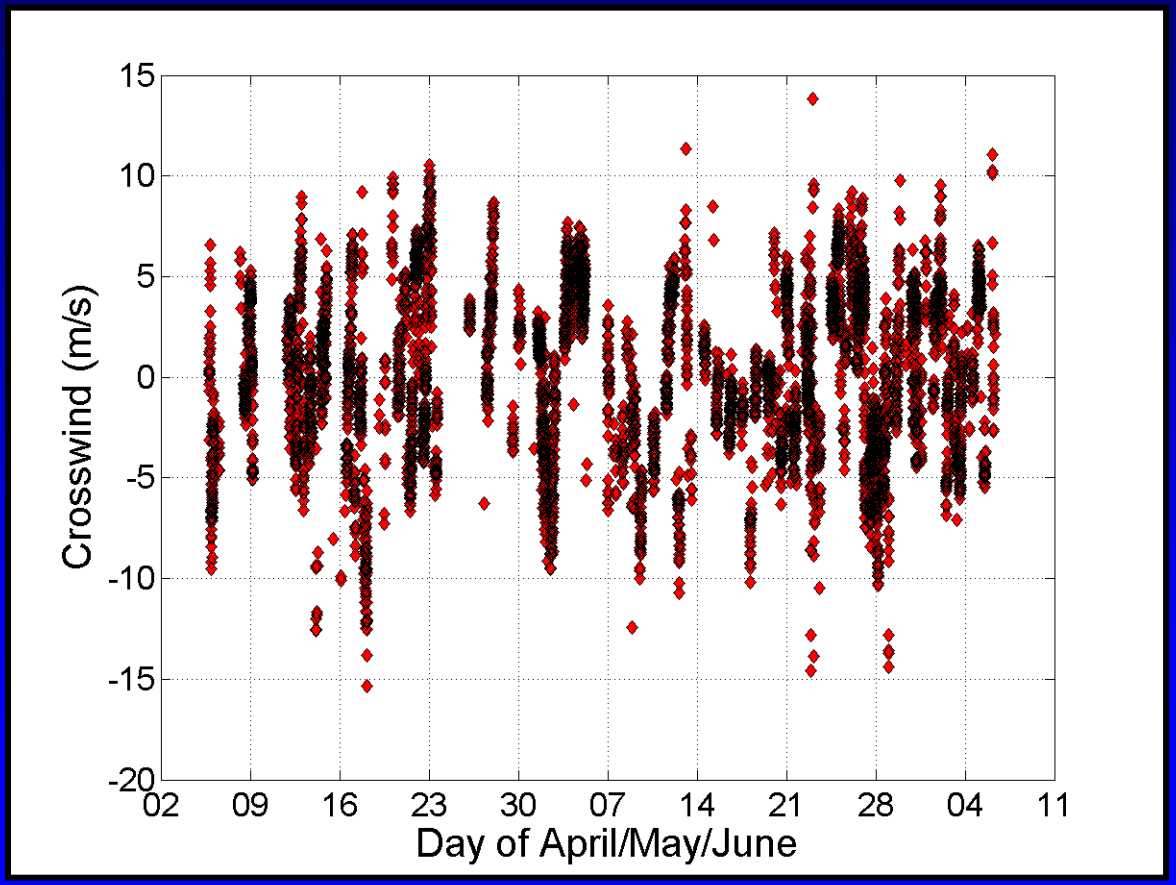


Let's look at another site…

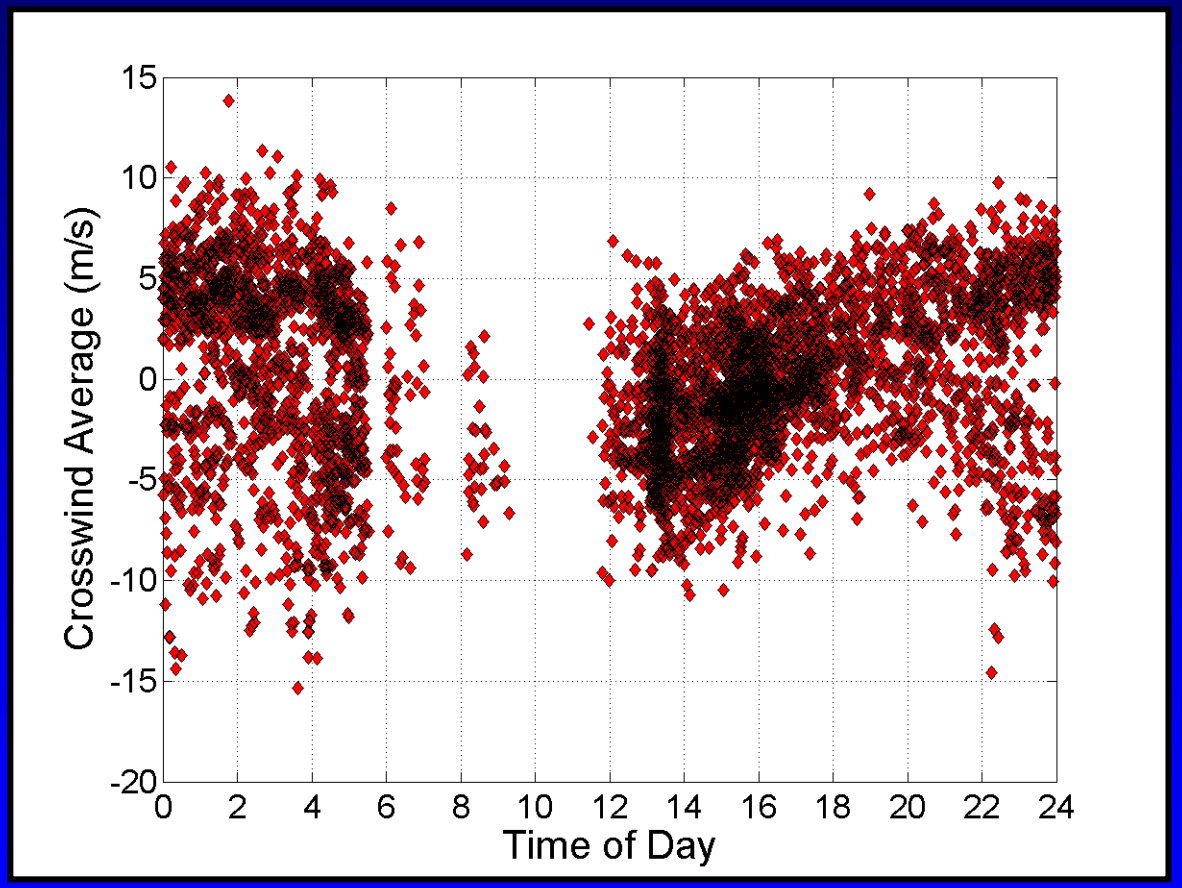
Denver 2006 OGE data

- 4898 landings used in the analysis
- 27 different aircraft types
- Glide slope altitude approximately 275 m
- LMCT pulsed-lidar
- Data set covers 9 weeks in April/May, 2006
- NASA provided the data for this analysis

DEN 2006 OGE Measured Lifetimes Day of Year



DEN 2006 OGE Average Crosswind Time of Day



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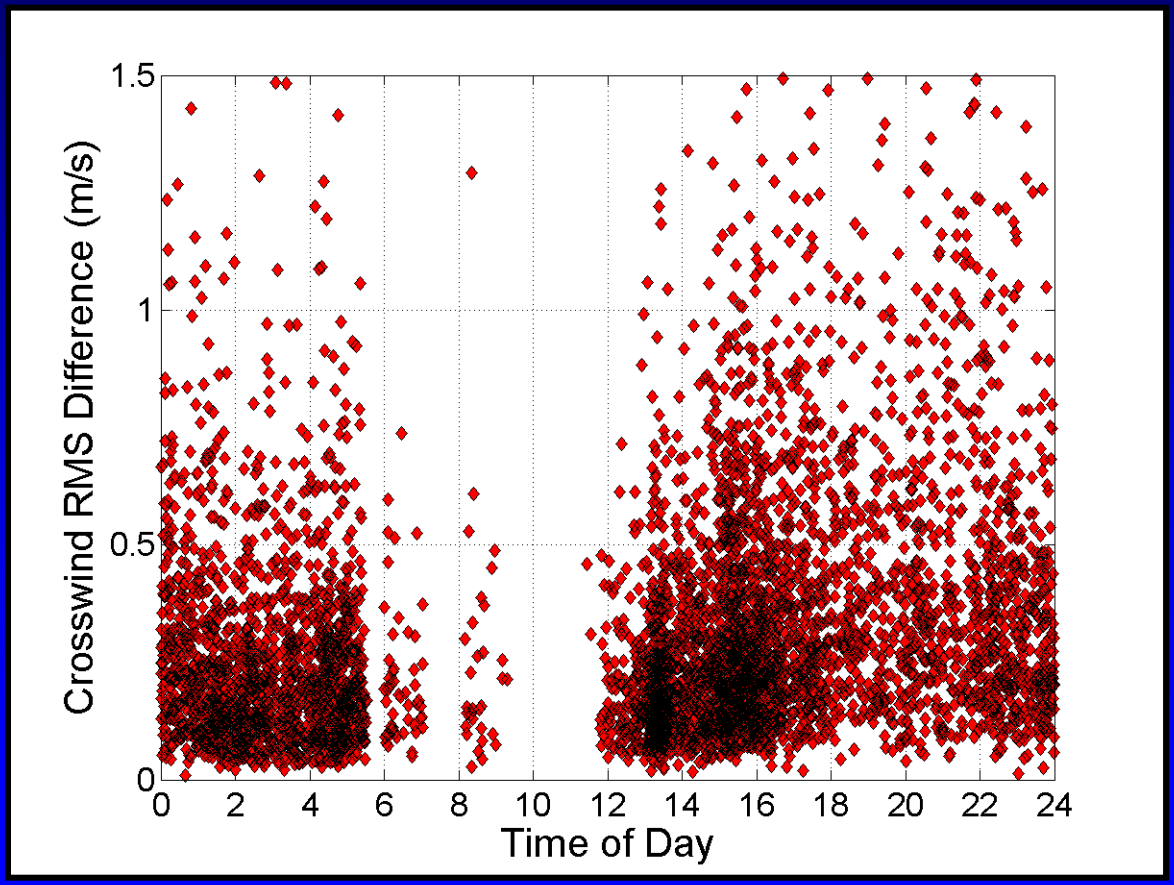

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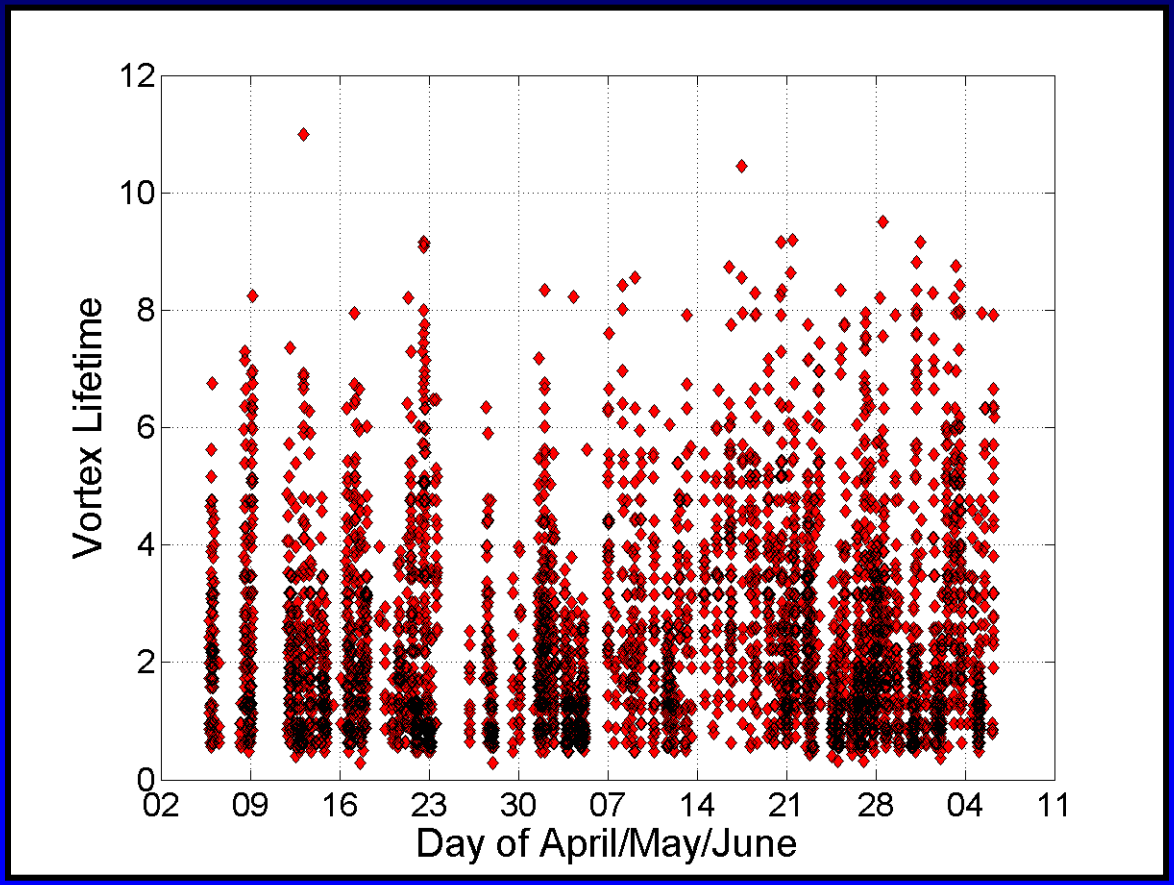

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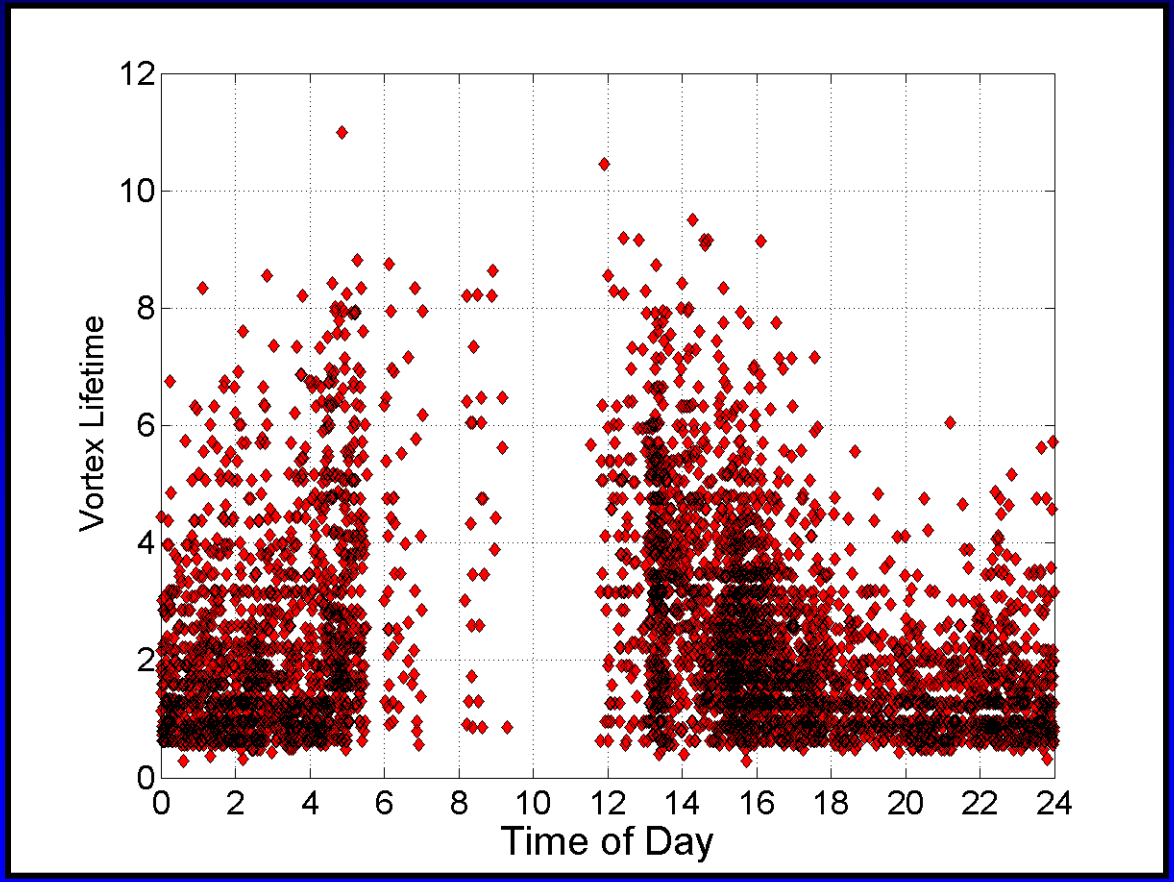

DEN 2006 OGE Bias

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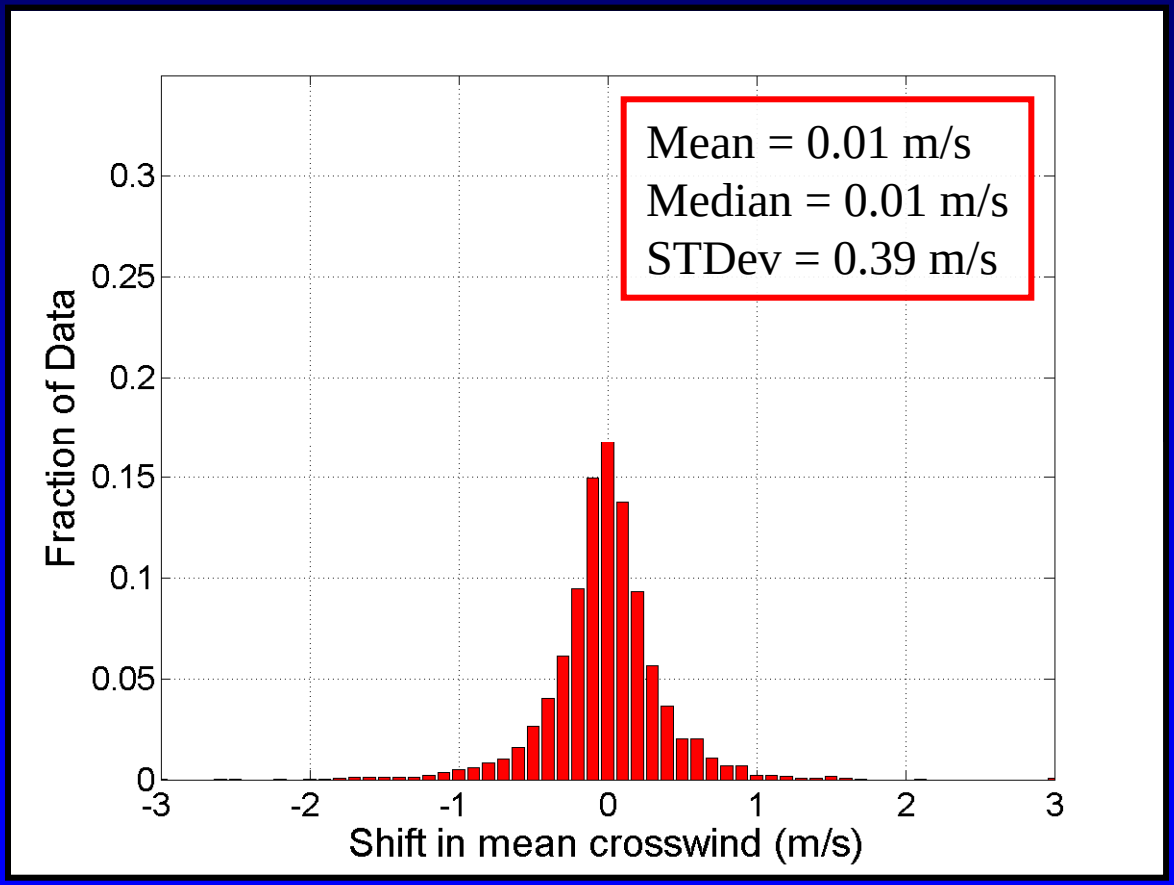

DEN 2006 OGE Standard Deviation

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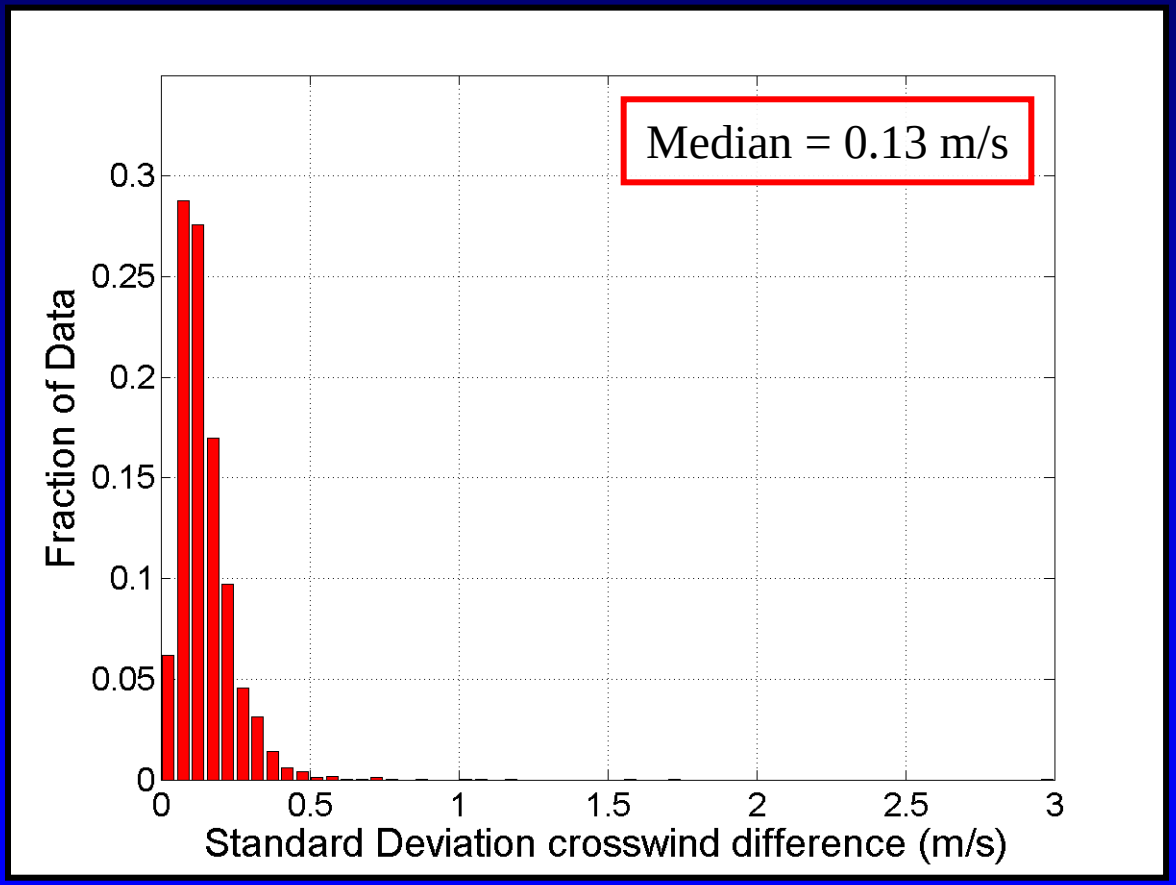
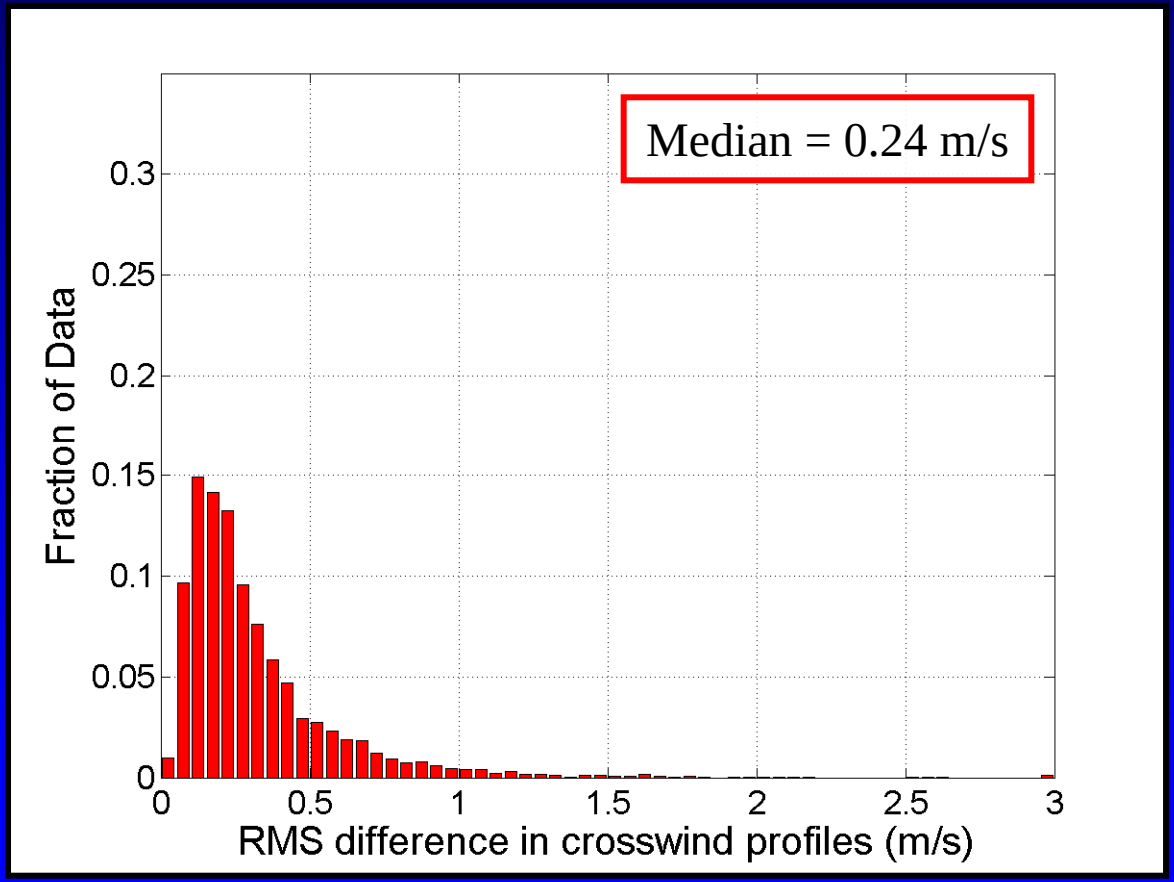


DEN 2006 OGE RMS difference

(RMS difference in wind profiles over vortex lifetime)



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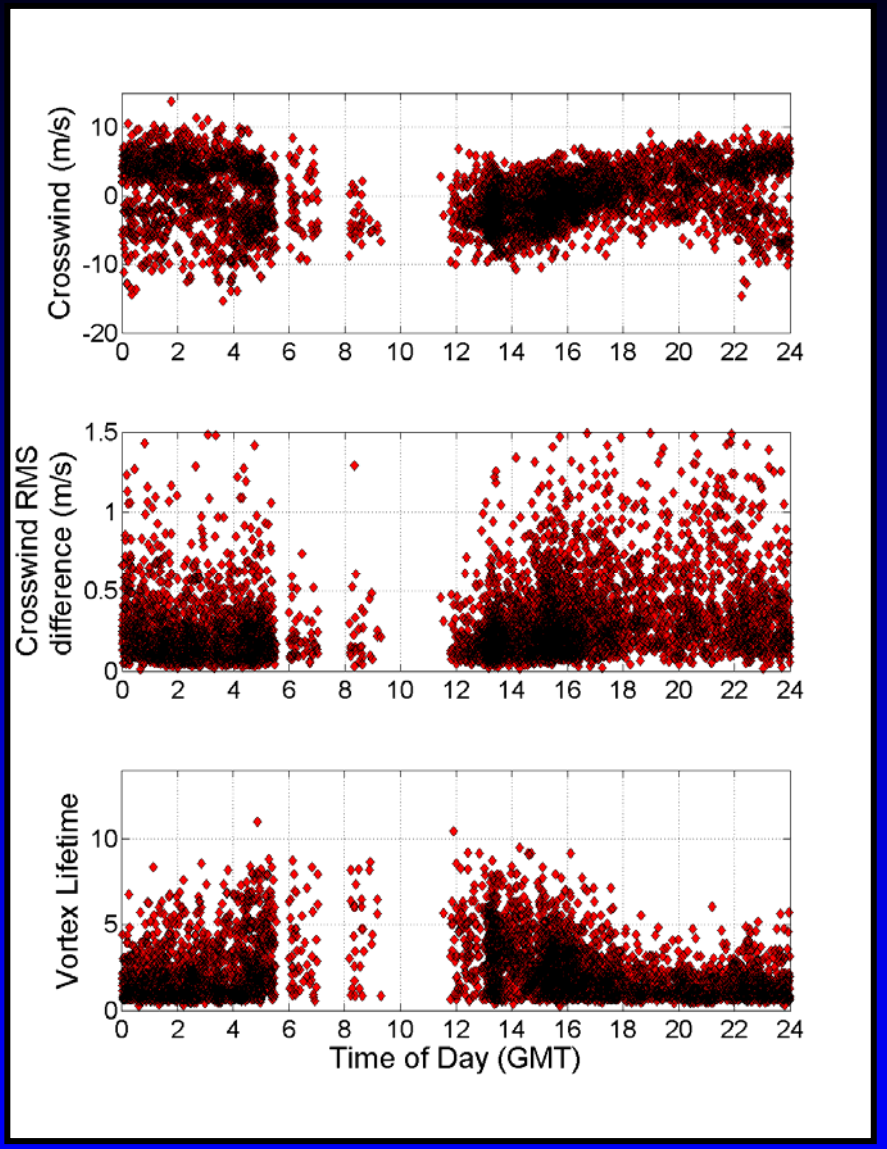
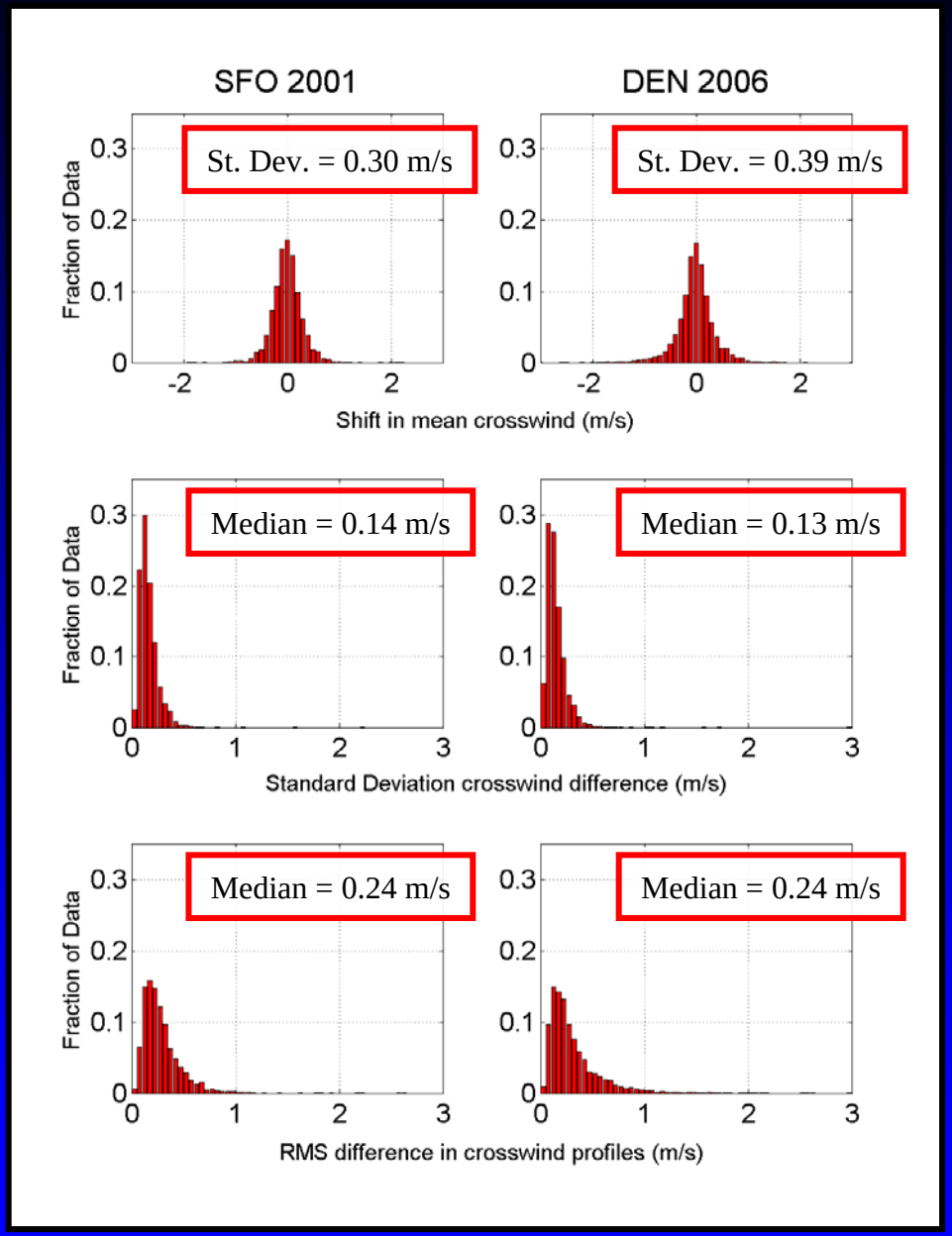


These observations agree at two different sites.

Distribution of lidar-measured line of sight wind speed fluctuations

1. Both SFO and DEN have similar distributions the fluctuations in the lidar-measured line of sight wind speeds observed
2. Both the mean shift of the wind AND changes in the shape of the profile are important



Within an Operational System…

- Information on the mean crosswind (and headwind) profile and the short-term variability of the crosswind (and headwind) AND their respective uncertainties is needed in
  - Real time, and
  - Should allow for a forecast up to 20 minutes ahead

Scientific Questions

1. Do other sites exhibit the similar distributions in the observed fluctuations in the lidar-measured line of sight winds?
2. Is the short-term variability in the lidar-measured line of sight wind speed correlated with environmental conditions, such as wind speed magnitude, wind shear, EDR (TKE) or stratification, or properties important to the sensor (or wake vortex algorithm) such as SNR?
3. Does the wind direction matter? Do the fluctuations in headwinds and crosswind exhibit different behavior?
4. Is the mean value and variability of wind profiles on relatively small spatial and temporal scales (order of 1 km or less, and 3 minutes or less, for example) predictable?

Conclusion

Fluctuations in lidar-measured line of sight winds over the vortex lifetime are similar in the DEN 2006 OGE and SFO 2001 OGE LMCT pulsed-lidar studies