3.1

Lecture 3.1 Horizontal Scaling

Derived from aircraft observations - a more complicated process than it first appeared to be.

We have used 4 different research aircraft:-

- **NASA ER-2,** flown at constant Mach number *M* where

$M = v_{aircraft}\,[\gamma R T]^{-0.5}$

- **NASA WB57F,** flown either at constant *M* or isobarically at constant pressure *P*

- **NOAA Gulfstream 4,** flown at constant *P*

- **NASA DC-8,** flown at constant *P*

- All the aircraft can be flown manually, something that is immediately obvious when it happens - the scaling is destroyed.

***** With knowledge of the vertical scaling, it becomes apparent that the manner of flight (autopilot) matters in extracting the horizontal scaling. (The ideal does not exist:- control to constant geometric altitude).

NASA ER-2

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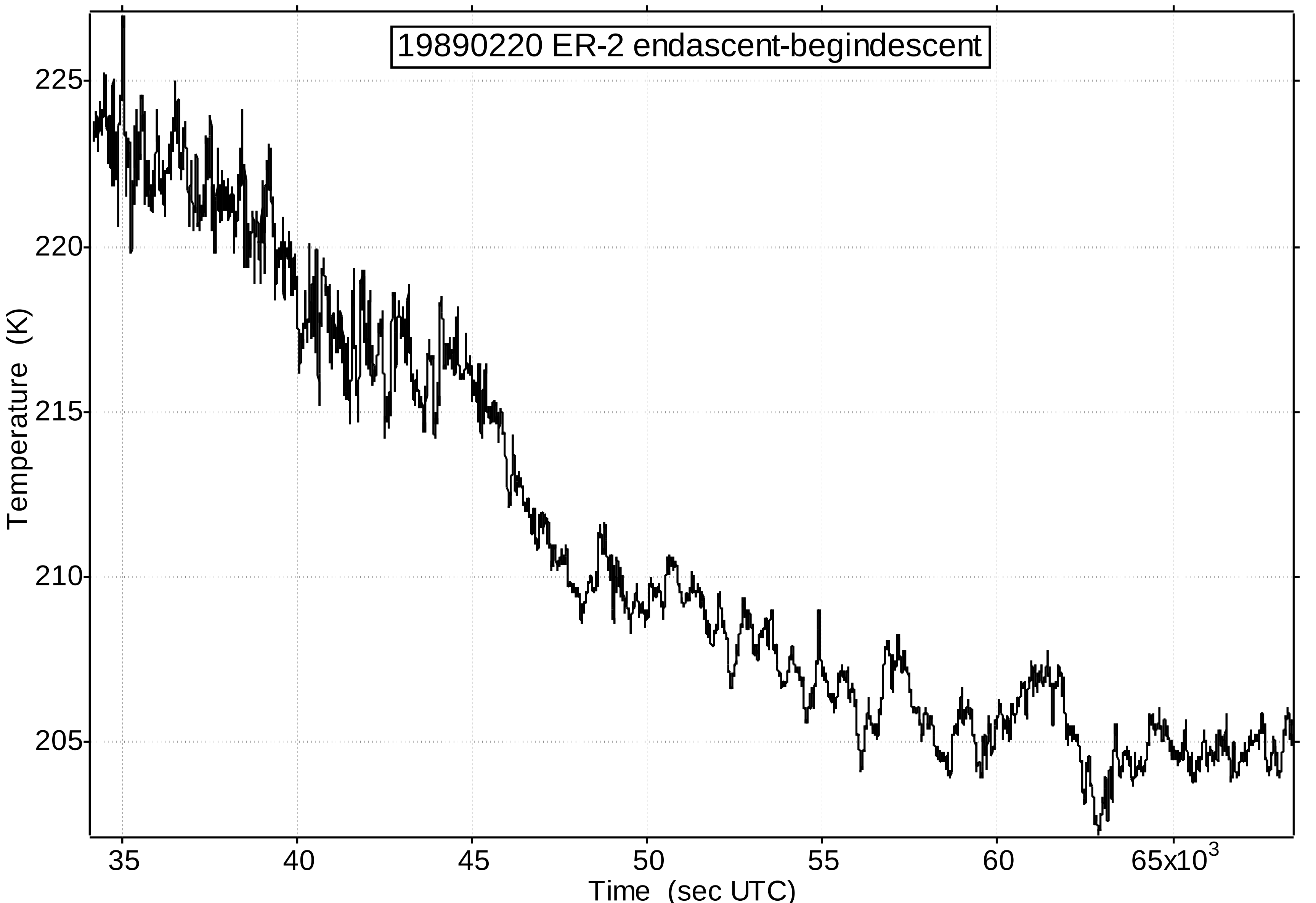
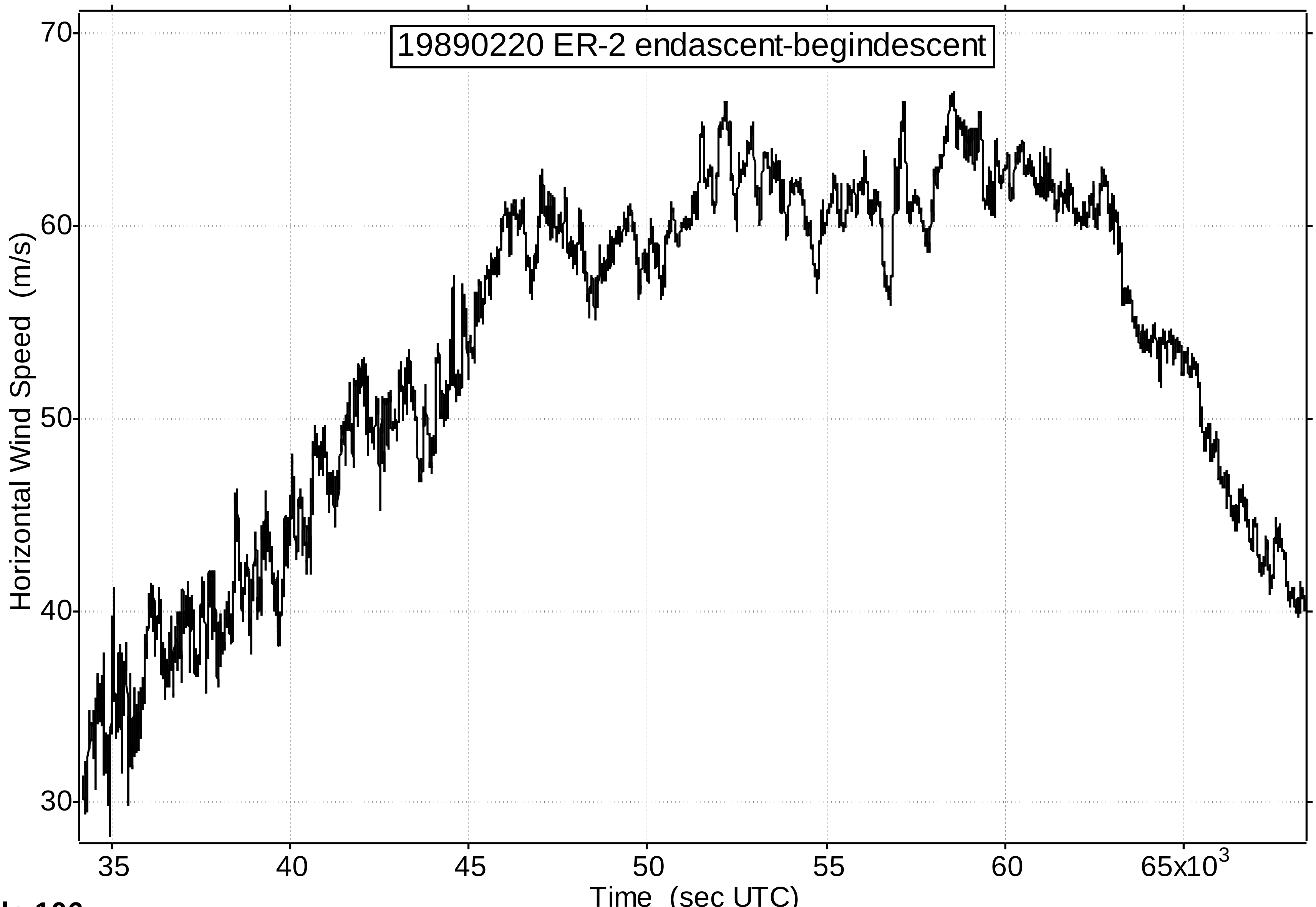
NOAA Gulfstream 4

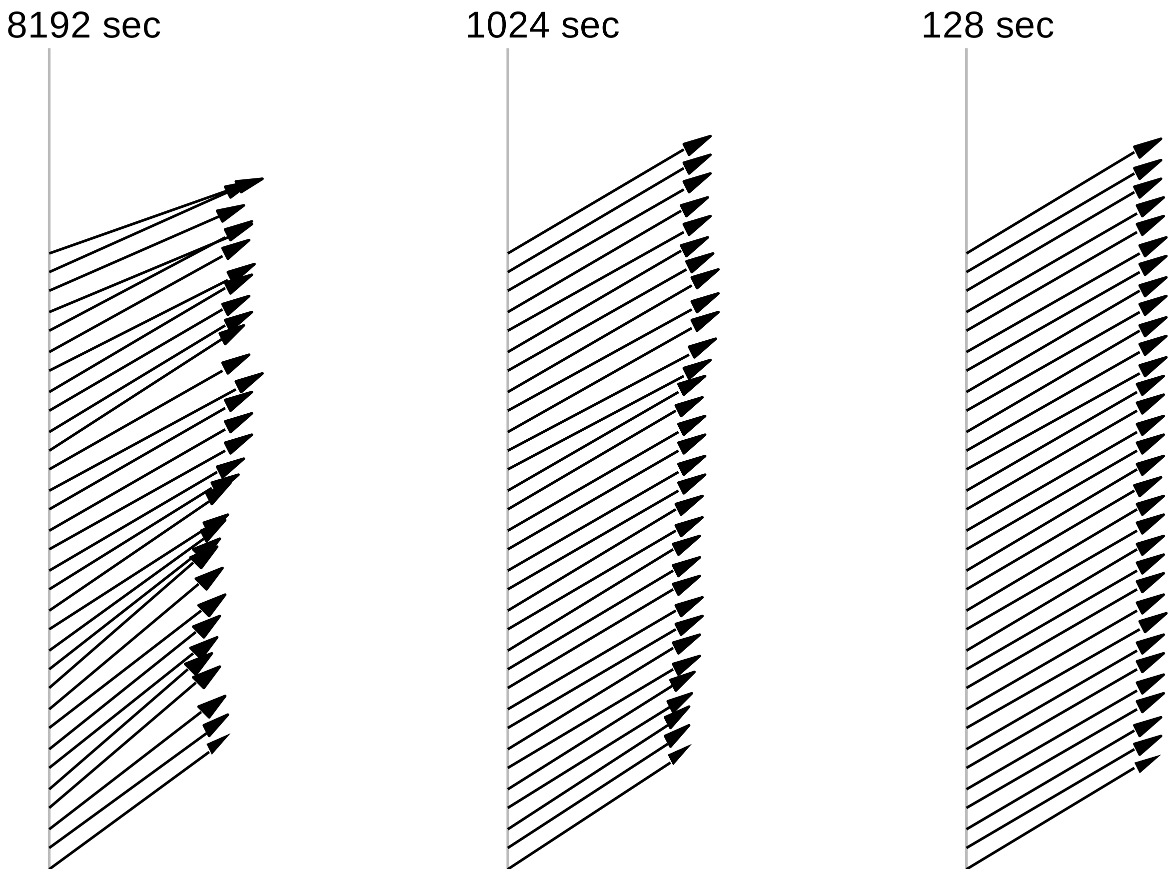
ER-2 flight into the polar night jet, Stavanger to Wallops Is.: *T*



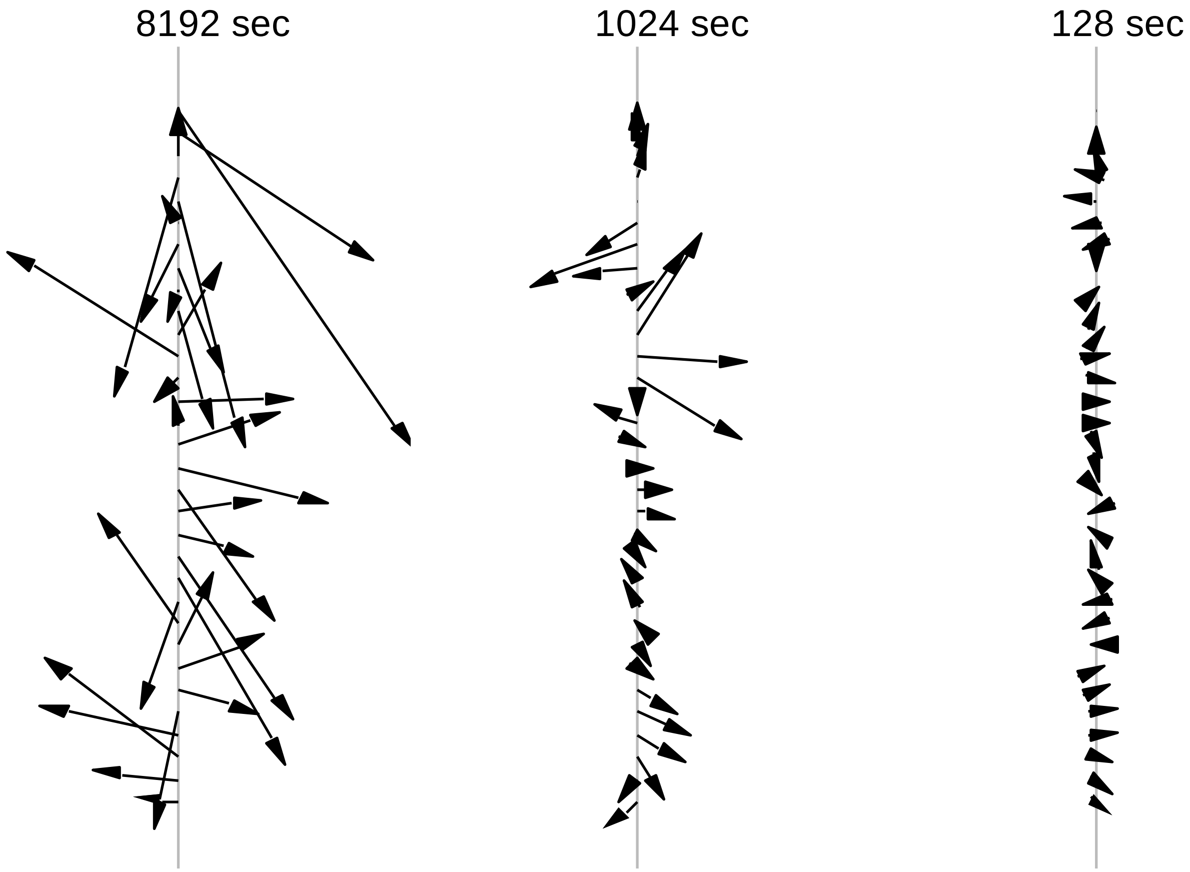
ER-2 flight into the polar night jet, Stavanger to Wallops Is.: $\sqrt{(u^2+v^2)}$



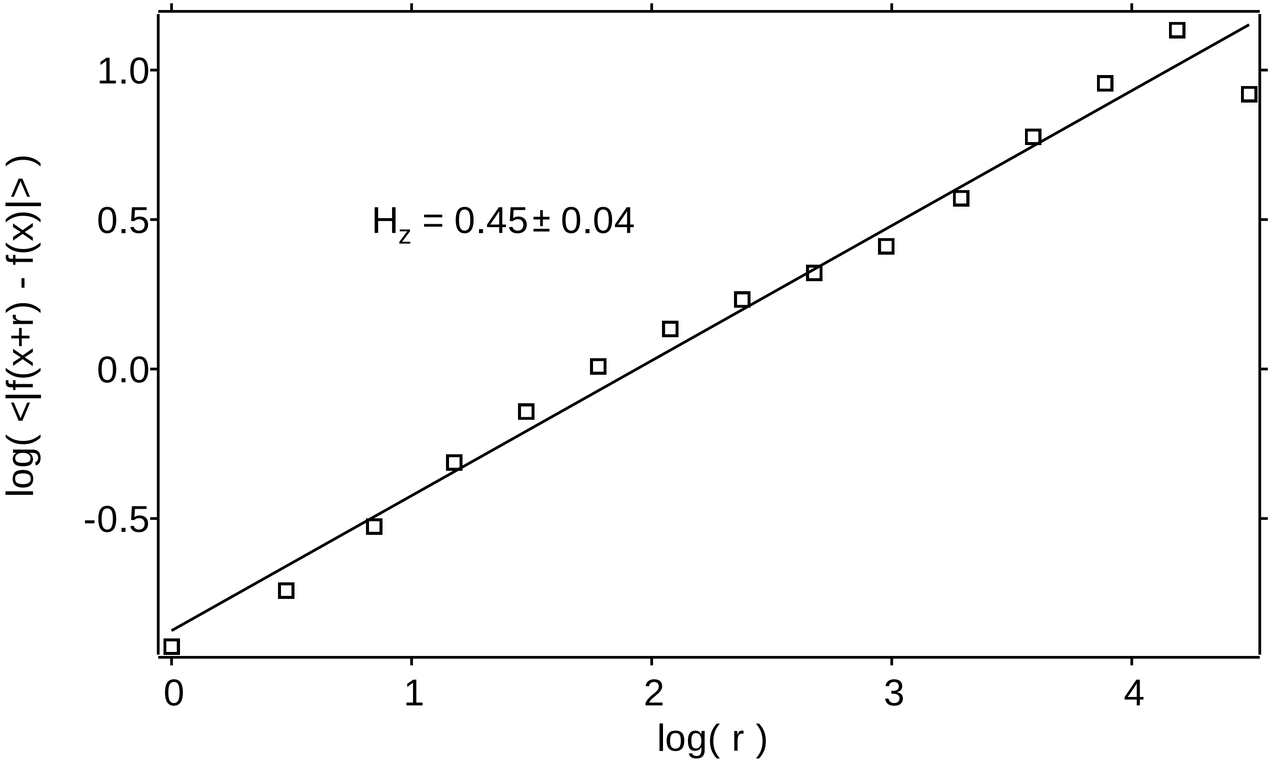
19890220 Wind Vectors Centred At (55^0 N,46^0 W)



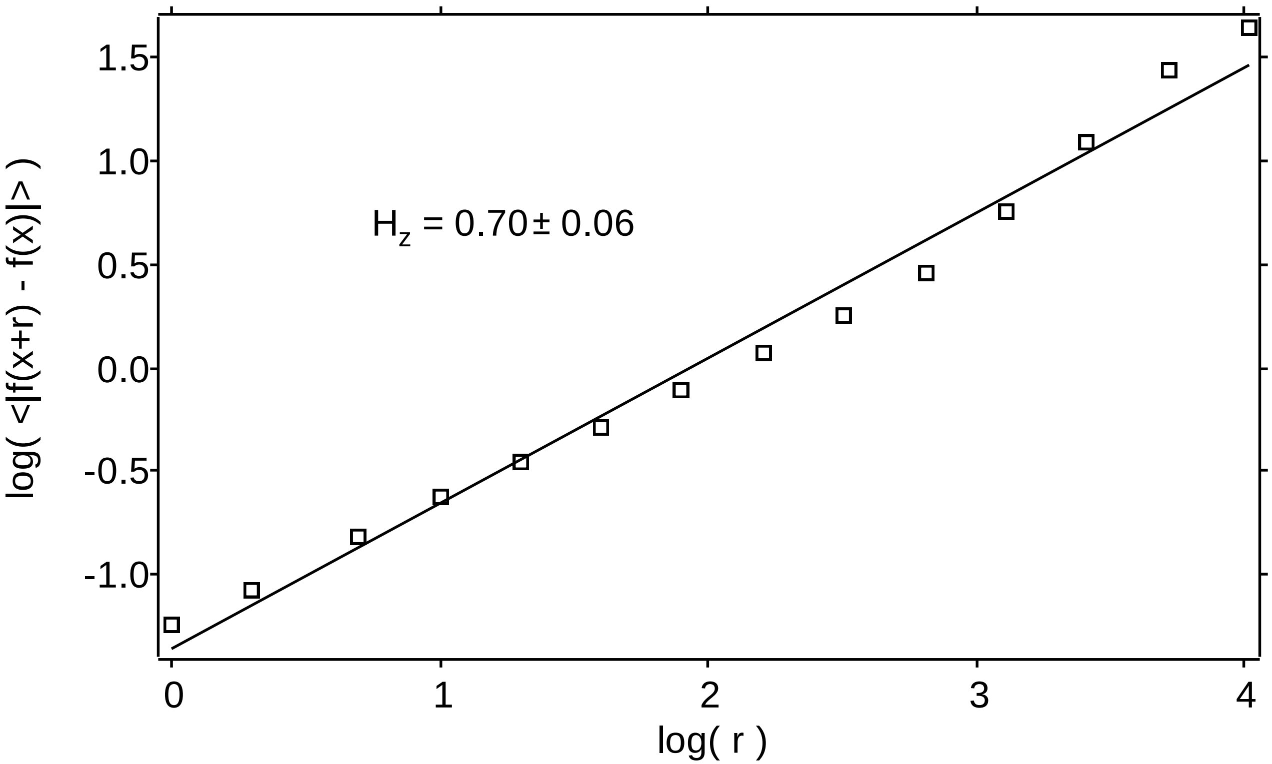
19890220 Wind Shear Vectors



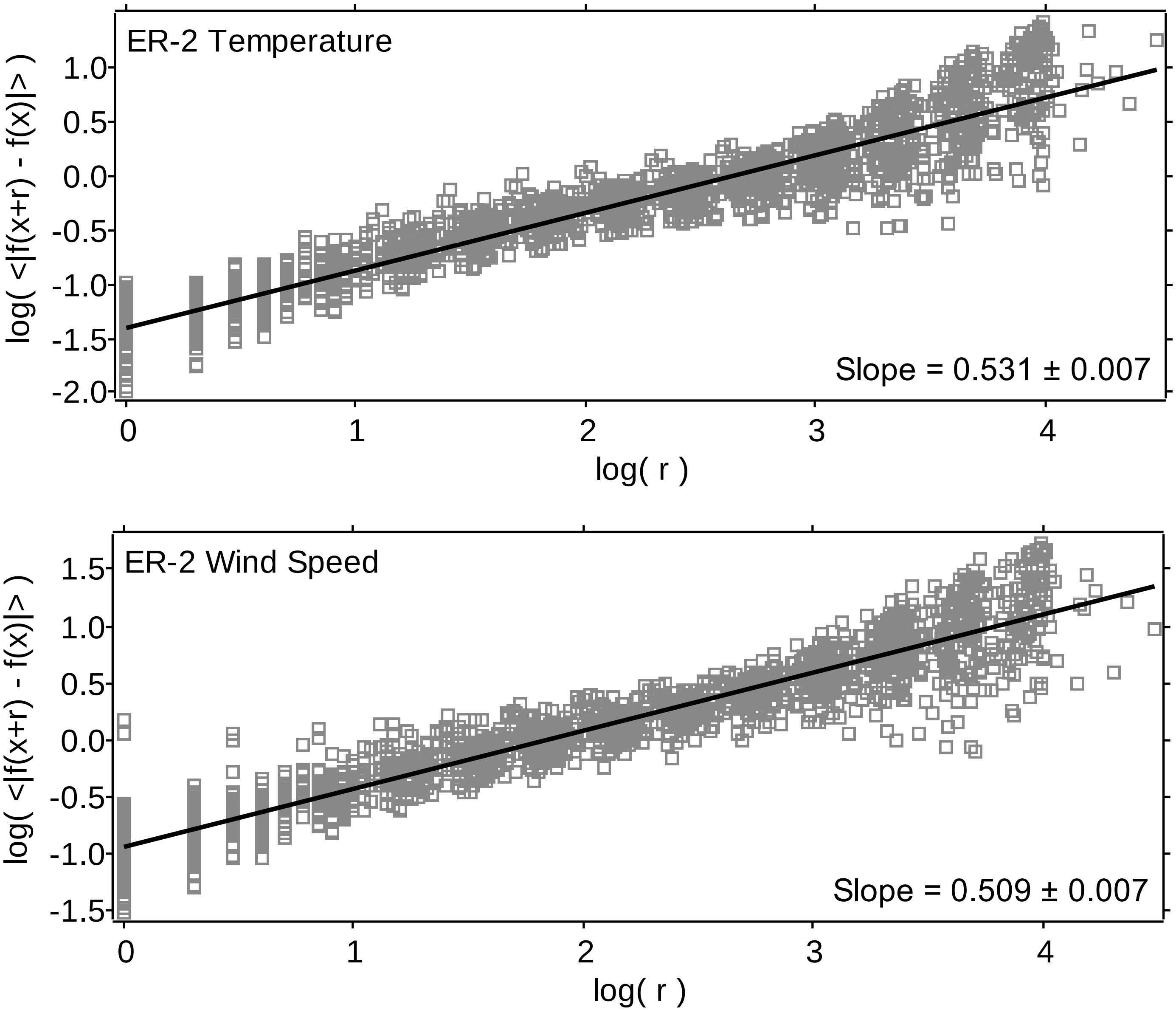
Scaling Calculation for 19890220 Wind Speed



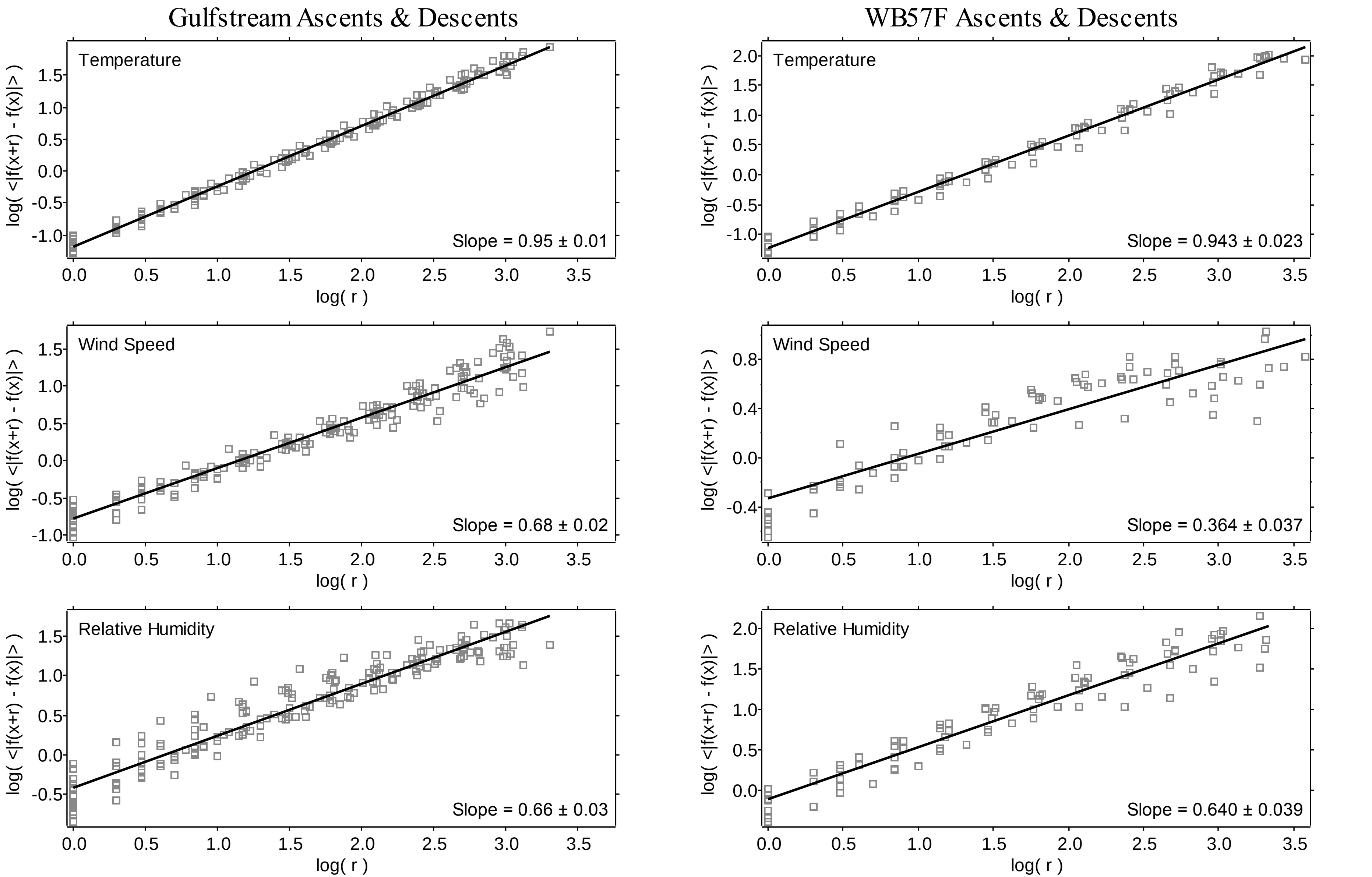
Scaling Calculation for 19941005 Wind Speed (44° S,173° E) to (65° S,180° E)



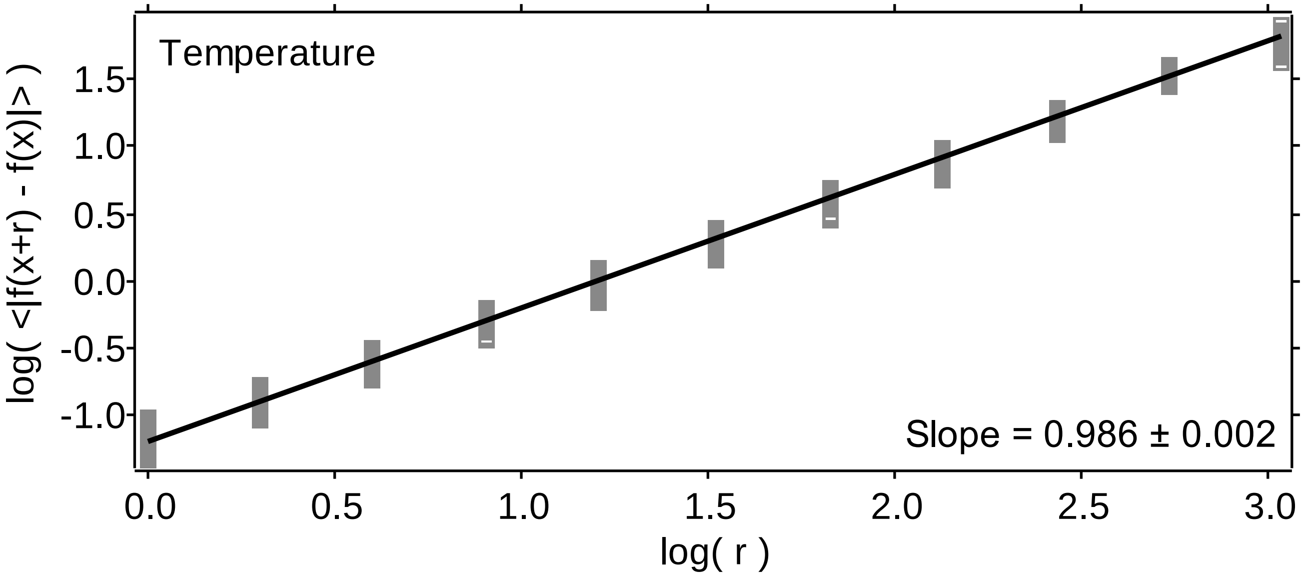
All ER-2 flight segments, 1987 - 2000, 90˚N -72˚S ˚

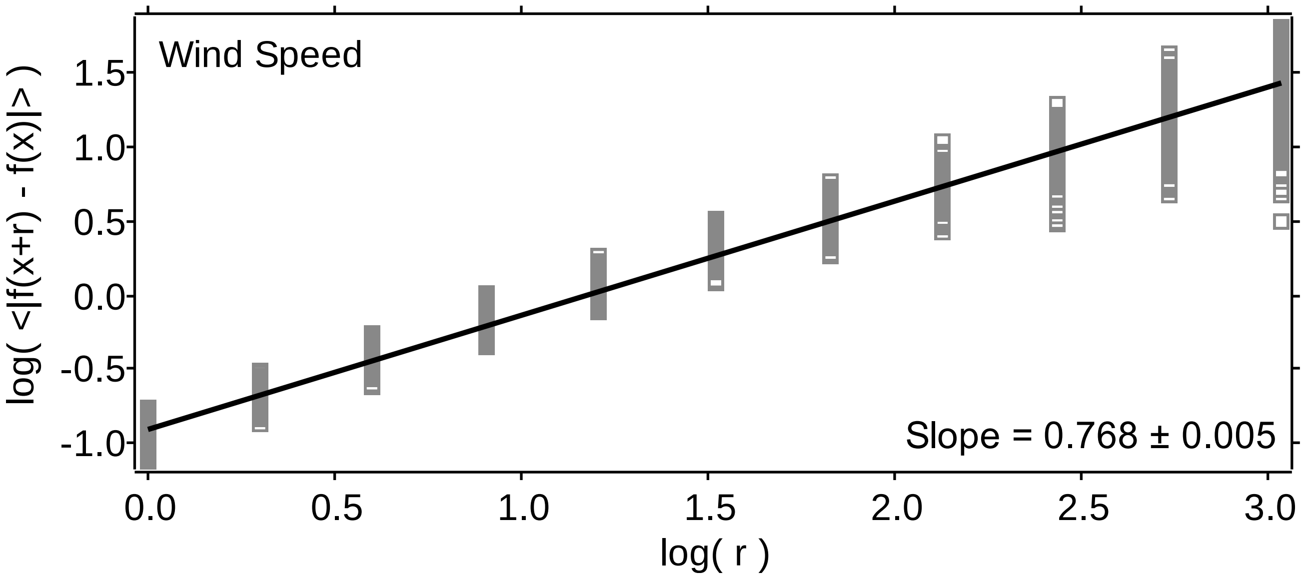


Aircraft ascents and descents, Jan-Mar 2004, 10˚- 60˚N, 84˚- 158˚W

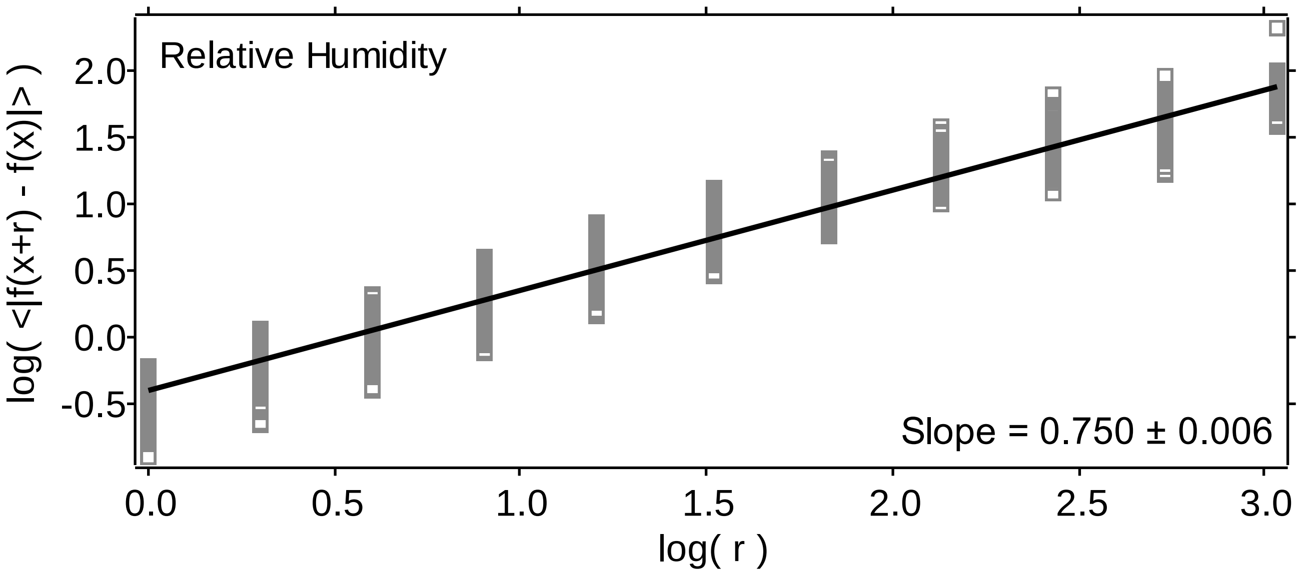


All 261 dropsondes, Winter Storms 2004, 10˚N-46˚N, 140˚W-172˚W, 20040229 - 20040314, NOAA G4





All 261 dropsondes, Winter Storms 2004, 10˚N-46˚N, 140˚W-172˚W, 20040229 - 20040314, NOAA G4

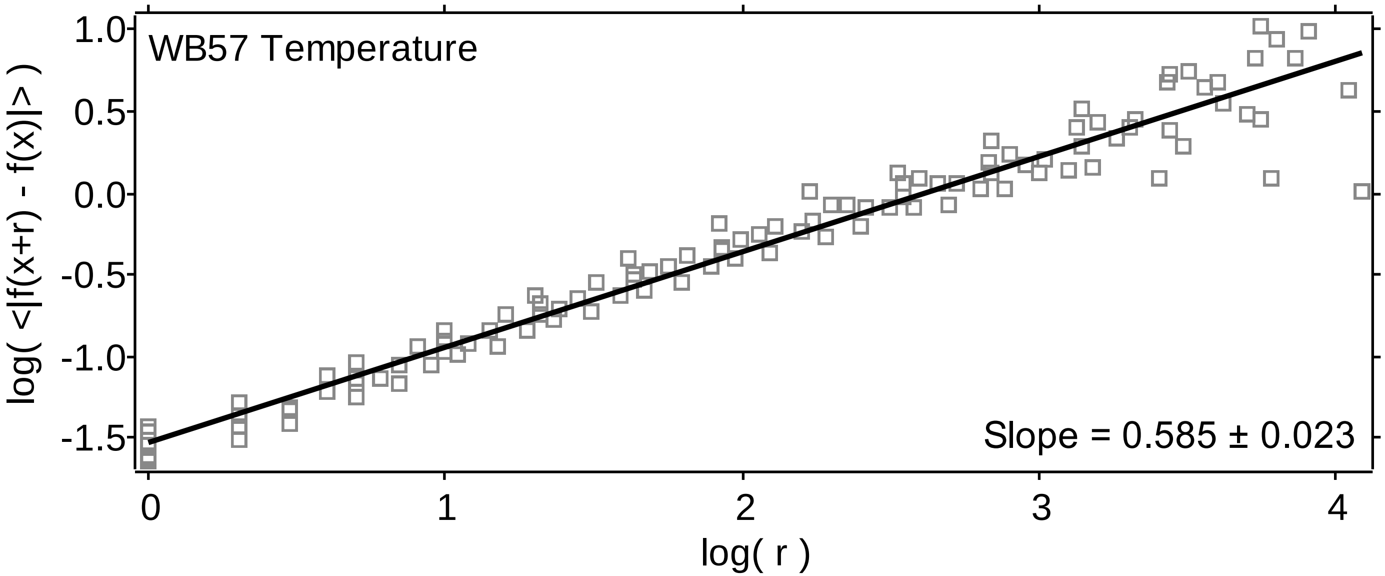


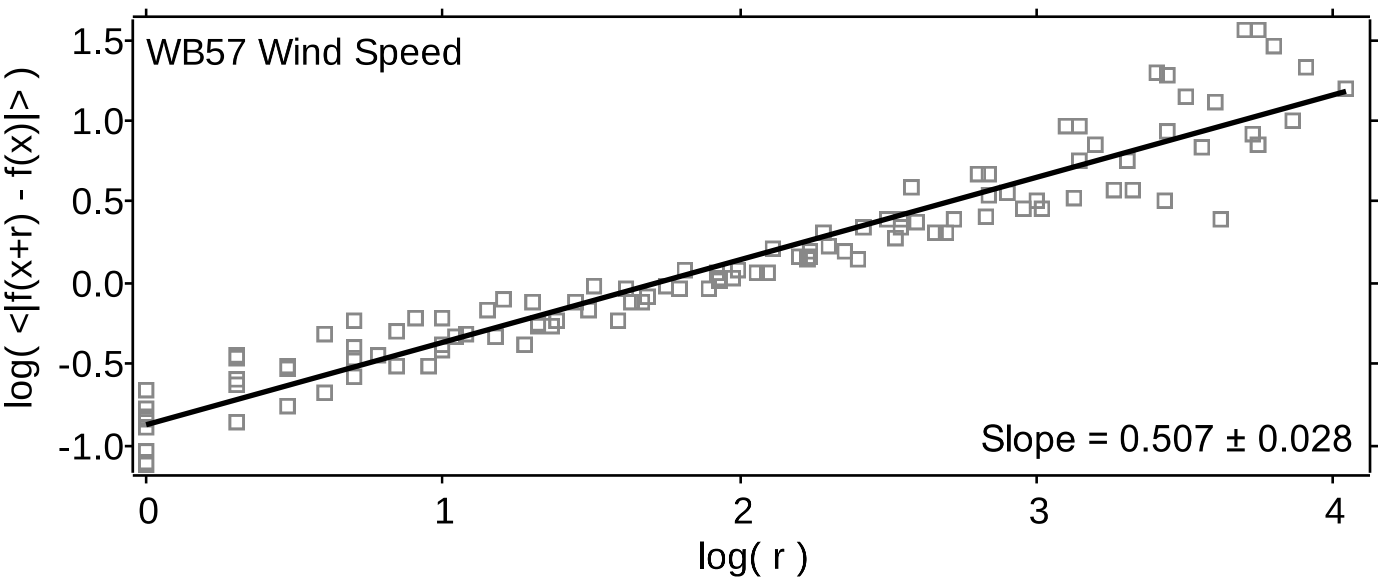
Scaling from G4 in Winter Storms 2004

N.B. Temperature scales differently than wind speed and humidity

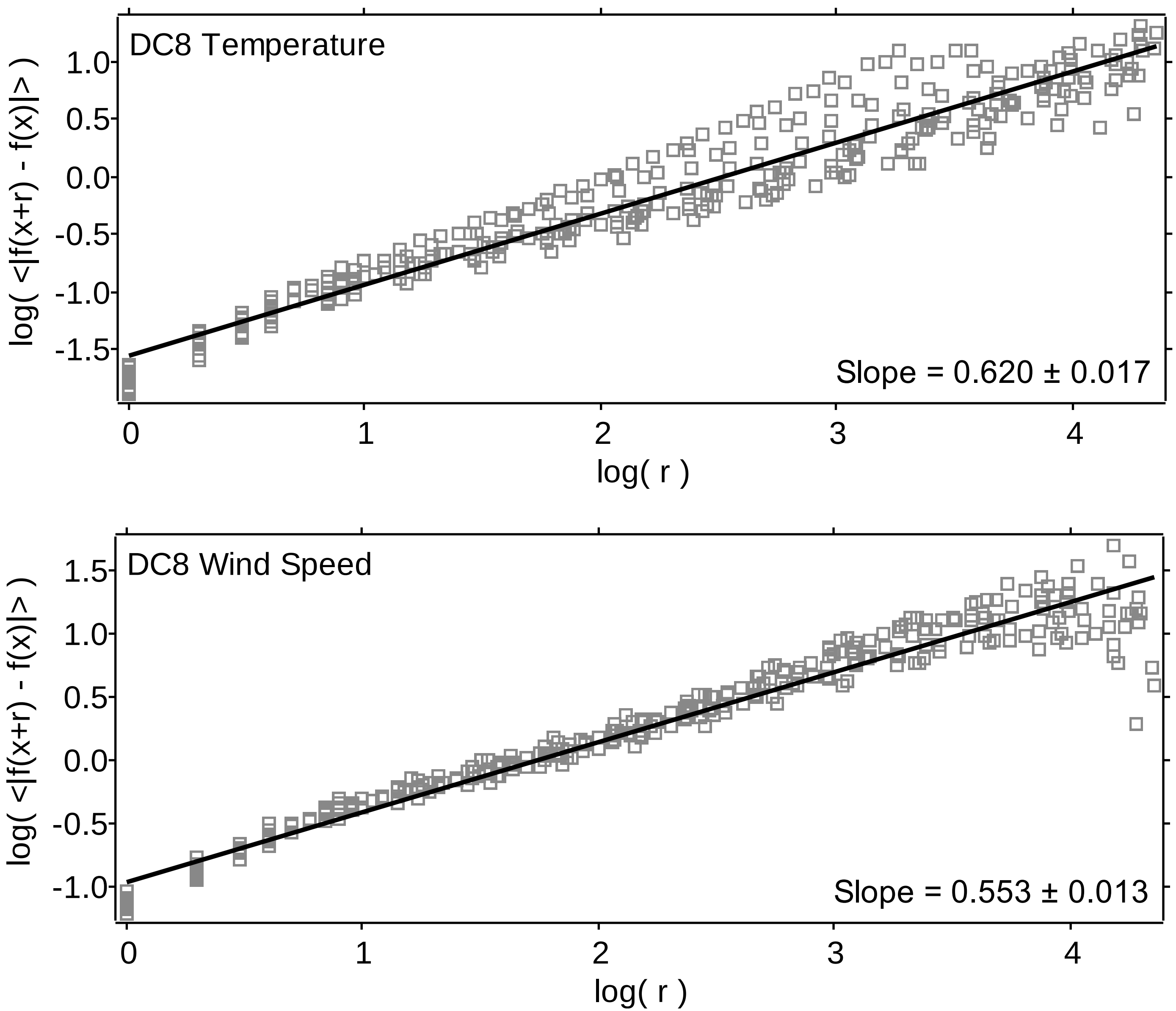
	Dropsondes	'Vertical' Aircraft Segments	'Horizontal' Aircraft Segments
Temperature	0.986 ± 0.002	0.95 ± 0.02	0.52 ± 0.02
Wind Speed	0.768 ± 0.005	0.68 ± 0.02	0.56 ± 0.02
Relative Humidity	0.750 ± 0.006	0.66 ± 0.03	0.45 ± 0.03

All WB57F 'horizontal' data near tropical tropopause 1998 - 1999 (WAM and ACCENT)

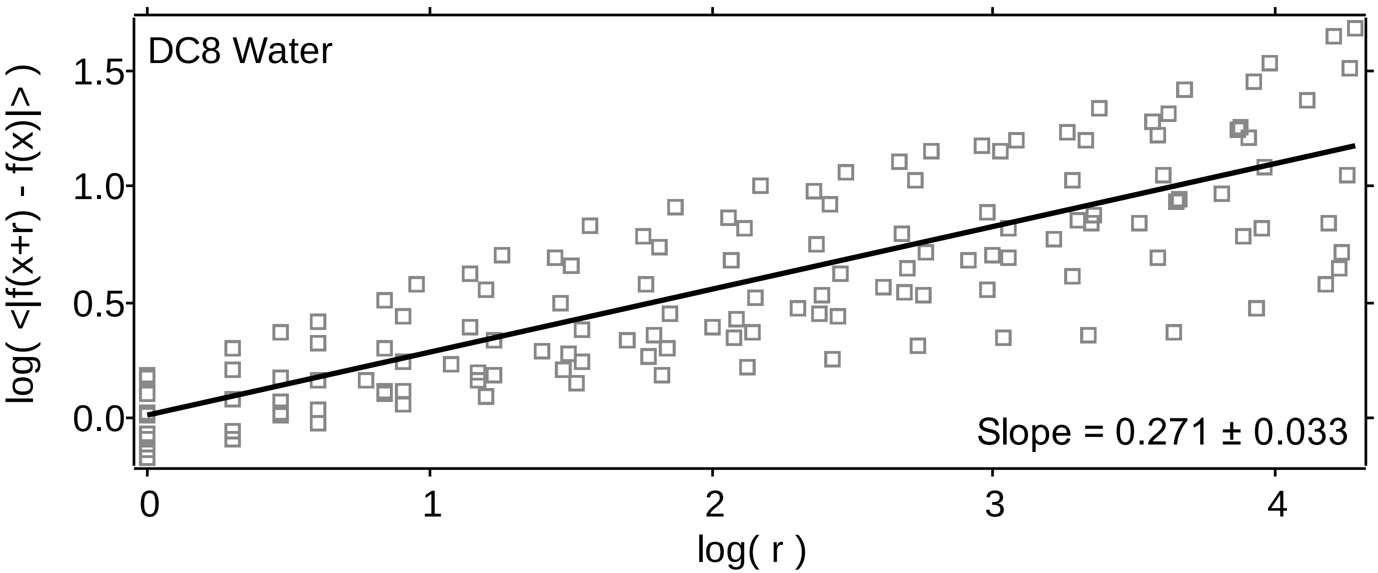




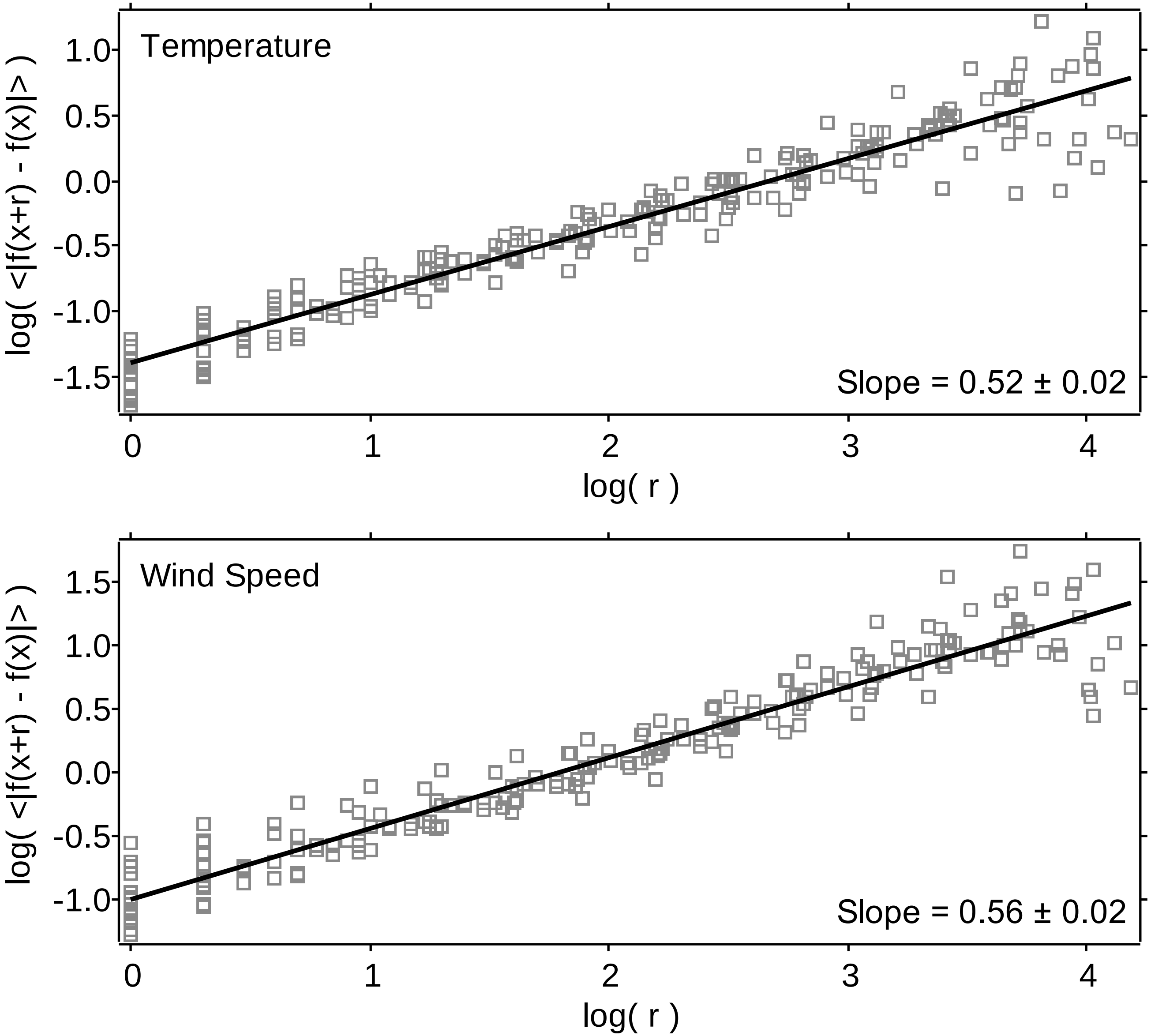
All DC-8 'horizontal' data, 44˚S - 90˚S, Aug-Sep 1987 (AAOE)



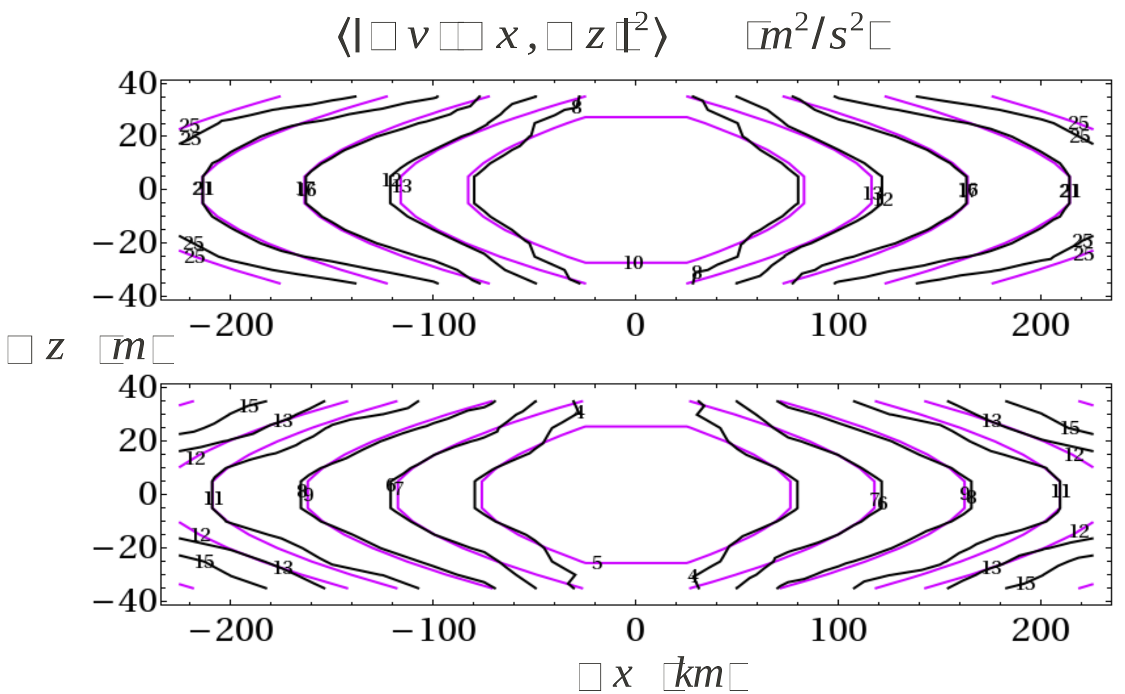
All DC-8 total water, 'horizontal', 44˚S - 90˚S, Aug-Sep 1987



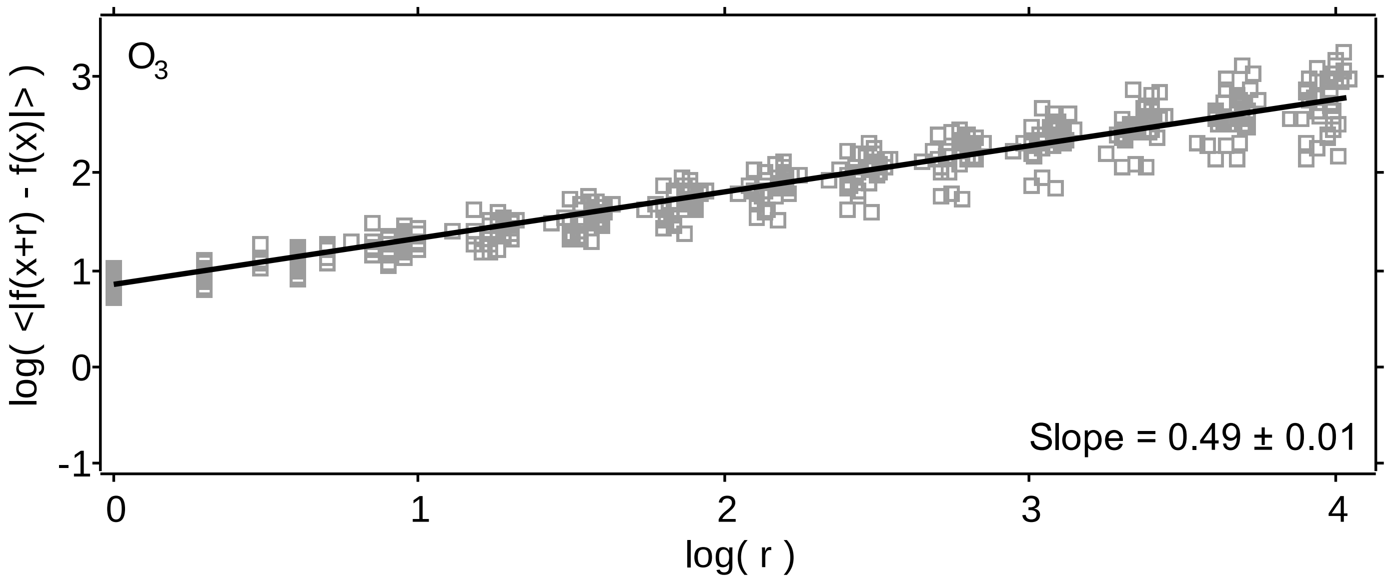
All NOAA G4 'horizontal' data, 10˚N-46˚N, 140˚W-172˚W 20040229 - 20040315

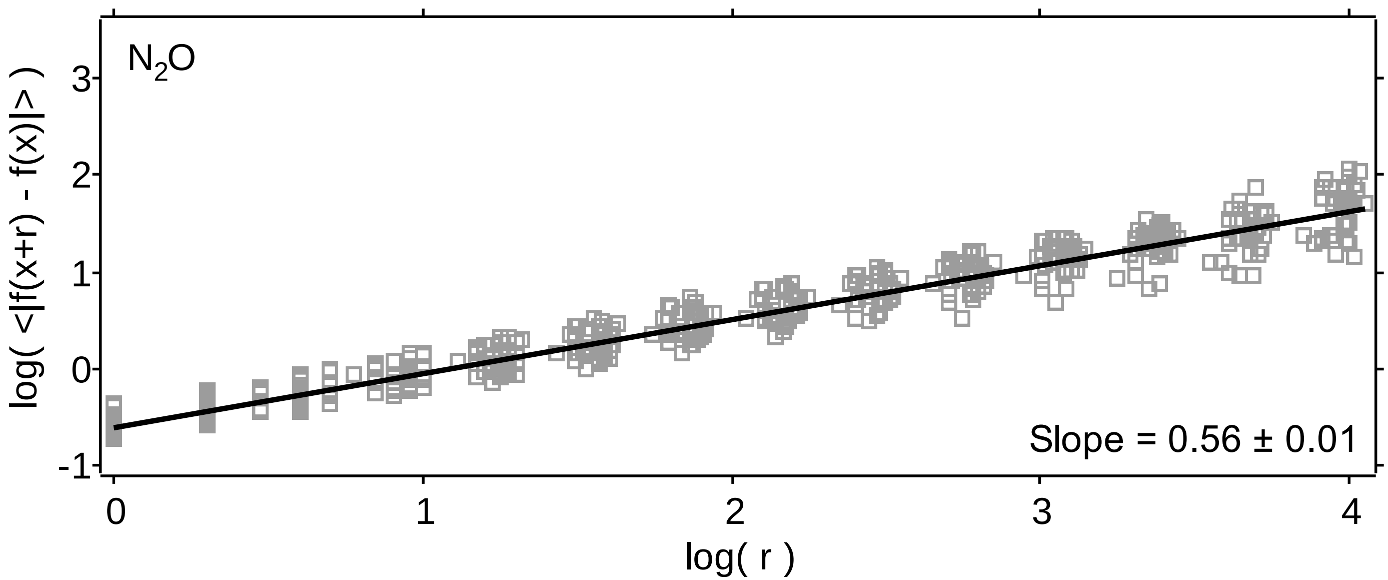


* Highest quality data, all TAMDAR flights over continental USA in 2009 between 5.0 and 5.5 km, about 14,500 flights, single aircraft only, 20 m deep (1.26 hPa) sections.
* *v* is wind speed, *x* is horizontal displacement, *z* is vertical displacement.
* Increments are squared, averaged and plotted below, transverse (top), longitudinal (bottom).
* Black is data, purple generalized scale invariance theory.
* Yields *H* = 0.57, close to GSI theory of 5/9.



All ER-2 ozone & nitrous oxide, 59˚N-70˚S, heavy SH weighting





Summary, Lecture 3.1

* Vertical and horizontal scaling are different.

* Aircraft trajectories are fractal, and mix horizontal and vertical scaling. If this is not allowed for by careful analysis of accurate, single aircraft data, illusory scale breaks appear.

* There is an altitude dependence in the vertical scaling of the horizontal wind, for which no theoretical explanation currently exists.

* The value of 0.56 ± 0.01 for $H(N_2O)$ is very strong evidence for the $H = 5/9$ scaling theory, since this tracer does not affect the trajectory of the aircraft.