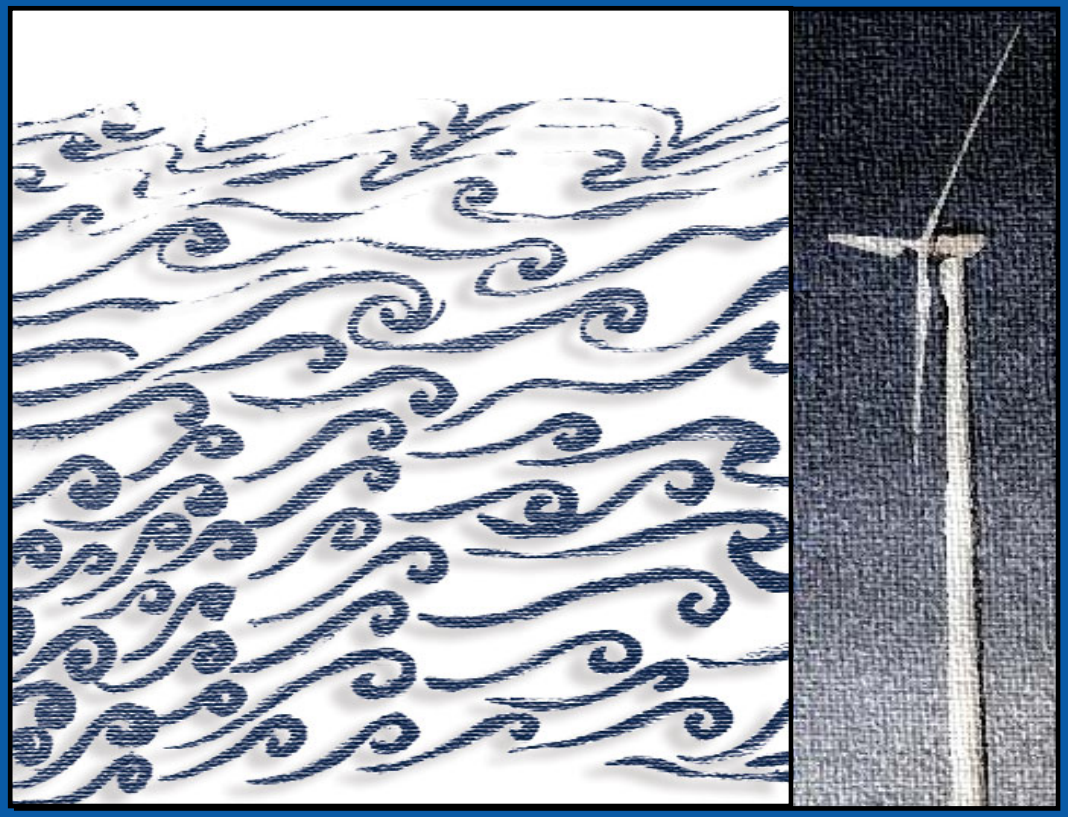
National Renewable Energy Laboratory
Innovation for Our Energy Future

Comparing Simulated Data with Measured Data



TurbSim Workshop
National Wind Technology Center

Bonnie Jonkman

September 23, 2008

Presentation Overview

- Definition of cases modeled
  - Cases for each of 5 site-specific models
- Results
  - Wind speed standard deviations
  - Reynolds stresses
  - Coherent Turbulent Kinetic Energy (CTKE)
  - Integral Length Scales
  - Spectra

Cases Modeled

- Data from each of 5 sets
  - Lamar LLJ project
  - NWTC/LIST
  - SeaWest Inflow
  - SeaWest Outflow
  - SeaWest Row 37
- Separated measured data into stability and wind speed categories
- Modeled available cases with wind speeds around 10-14 m/s as well as highest and lowest wind speeds in stability category

Stability Category	Richardson Number Range
1	$Ri \leq -1.0$
2	$-1.0 < Ri \leq 0$
3	$0 < Ri \leq 0.1$
4	$0.1 < Ri \leq 0.25$
5	$0.25 < Ri$

Velocity Category	Wind Speed Range
$i = 3, 5, \ldots, 21$	$\lvert u - i \rvert < 1\,\mathrm{m/s}$

Cases Modeled

Wind Speed Bins										Stability Category
3	5	7	9	11	13	15	17	19	21	
N										1
		L N O	L N I O R	L N I O R	L N I O	O			L N I	2
		L N O	L N I O R	L N I O R	L N I O R	O		I	L N	3
		L N O	L N R	L N R	L			L	L	4
		L	L	L	L		L			5

L = Lamar LLJ (21 cases)

I = SeaWest Inflow (8 cases)

R = SeaWest Row 37 (7 cases)

N = NWTC/LIST (14 cases)

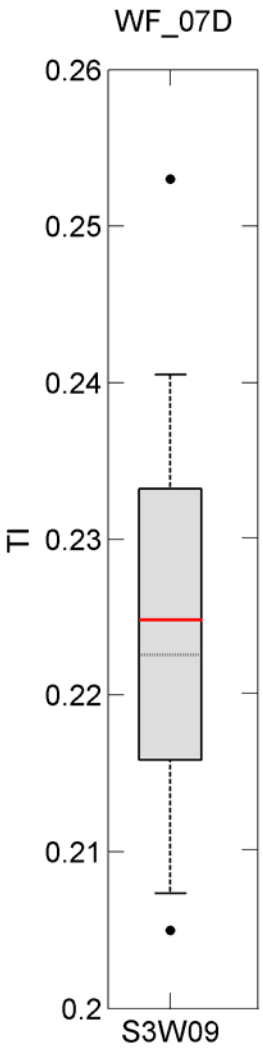
O = SeaWest Outflow (11 cases)

TurbSim Setup

- Each site-specific model in TurbSim v1.40 was run for the corresponding data categories
  - TurbSim Meteorological Inputs:
    - Richardson number (median *Ri* of the data in the category)
    - hub-height wind speed (median *WS* of the data in the category)
    - all others were “default”
  - Other Boundary Conditions:
    - 2-3 m grid spacing
  - 31 seeds for each case

Comparisons

- Simulated data distributions compared with measured data using box plots
  - "Box" top and bottom indicate 25th and 75th percentiles
  - Dotted black line indicates the median (50th percentile)
  - Solid red line indicates mean value
  - "Whiskers" (lines extending above and below box) are drawn to the 10th and 90th percentiles
  - Dots are drawn at the 5th and 95th percentiles



Comparisons

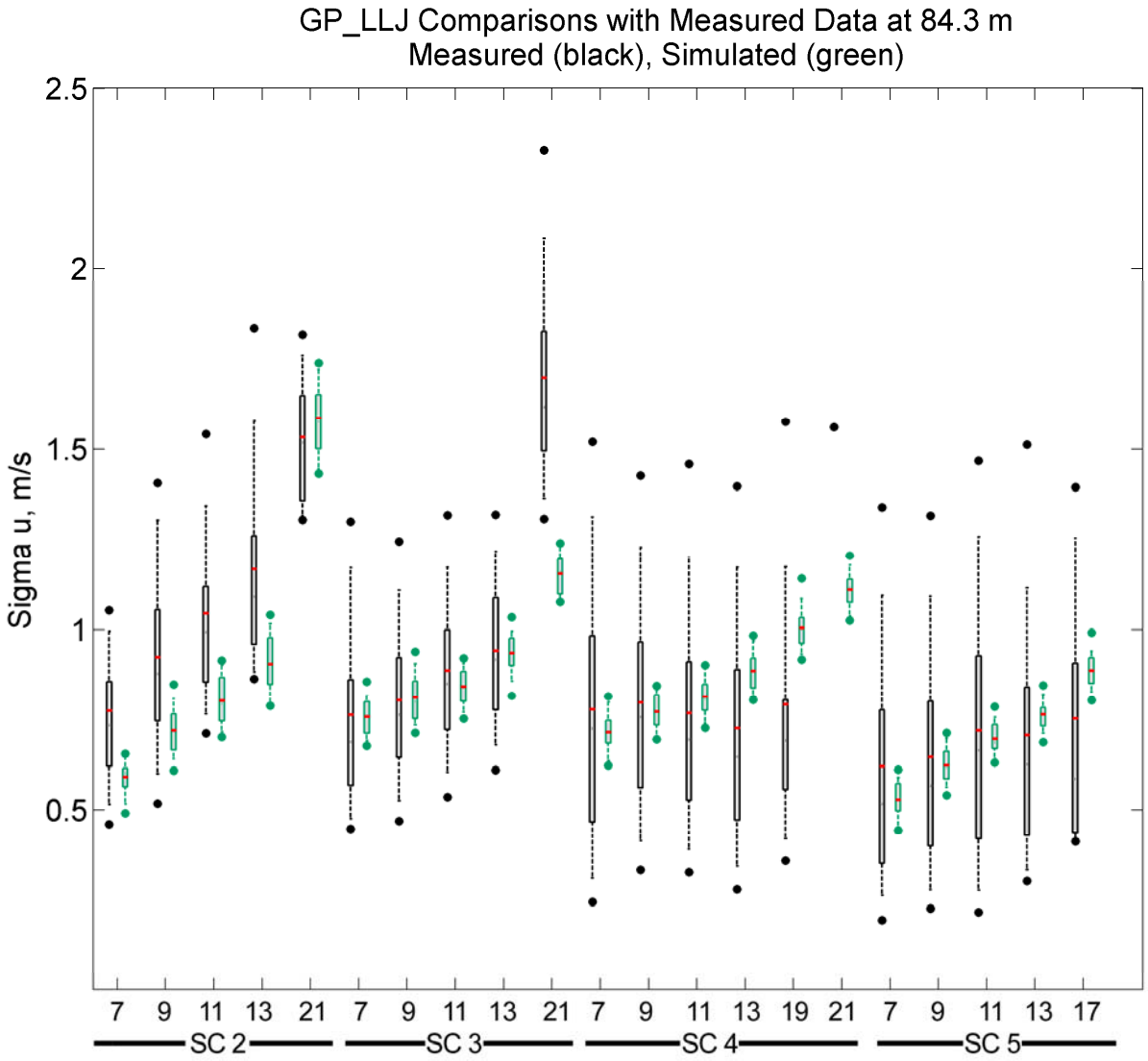
- Parameters compared:
  - Wind speed standard deviations
  - Reynolds stresses
  - Coherent Turbulent Kinetic Energy (CTKE)
  - Integral Length Scales
  - Spectra

GP_LLJ Model vs. Lamar LLJ Data

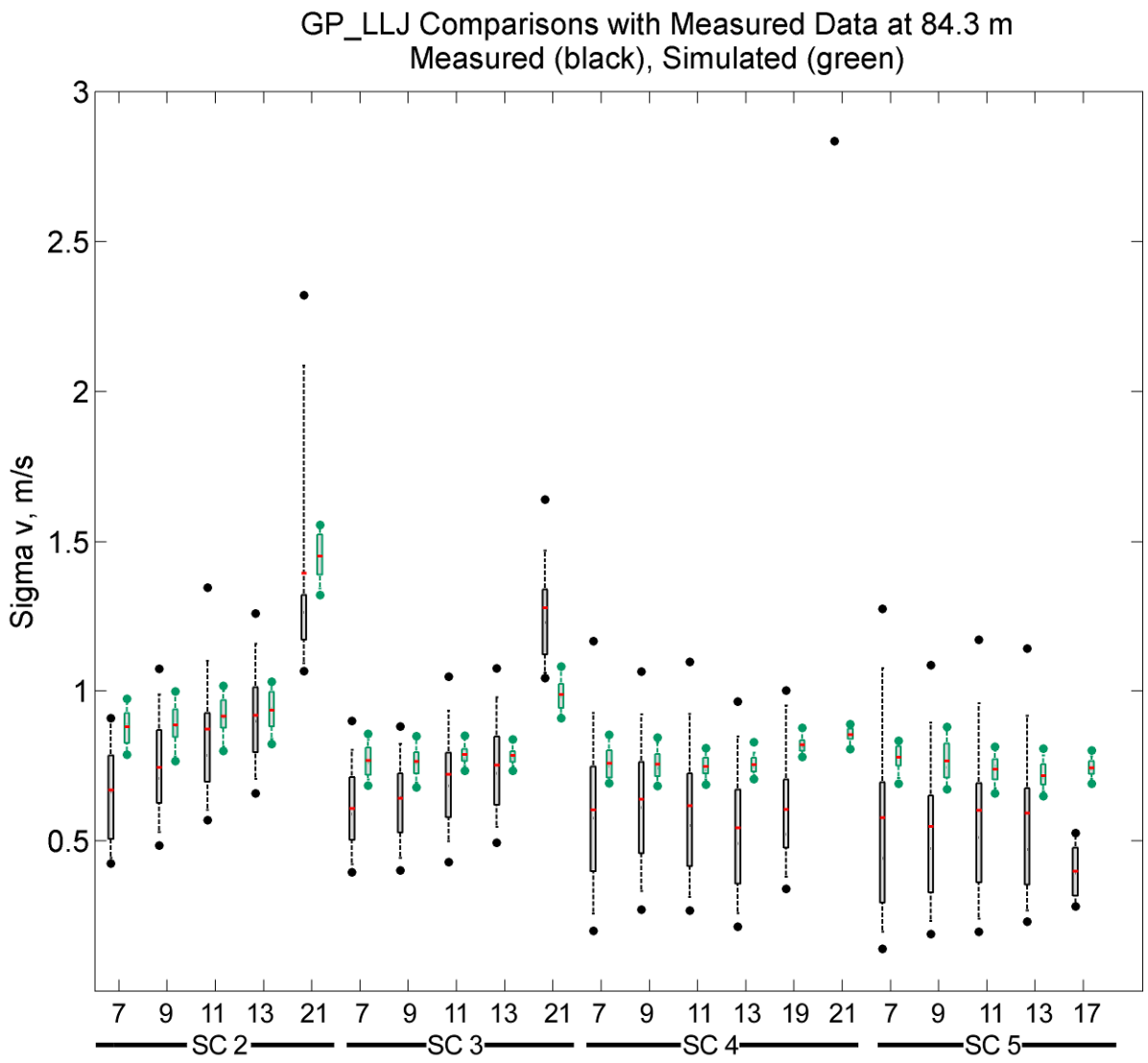
- 21 cases, 31 random seeds each
- 25x25 grid
- 3.5-m grid spacing
- Comparisons at ~85-m hub-height

Stability Category	Wind Speed Bins 3	5	7	9	11	13	15	17	19	21
1	N									
2			L N O	L N I O R	L N I O R	L N I O	O			L N I
3			L N O	L N I O R	L N I O R	L N I O R	O		I	L N
4			L N O	L N R	L N R	L			L	L
5			L	L	L	L		L		

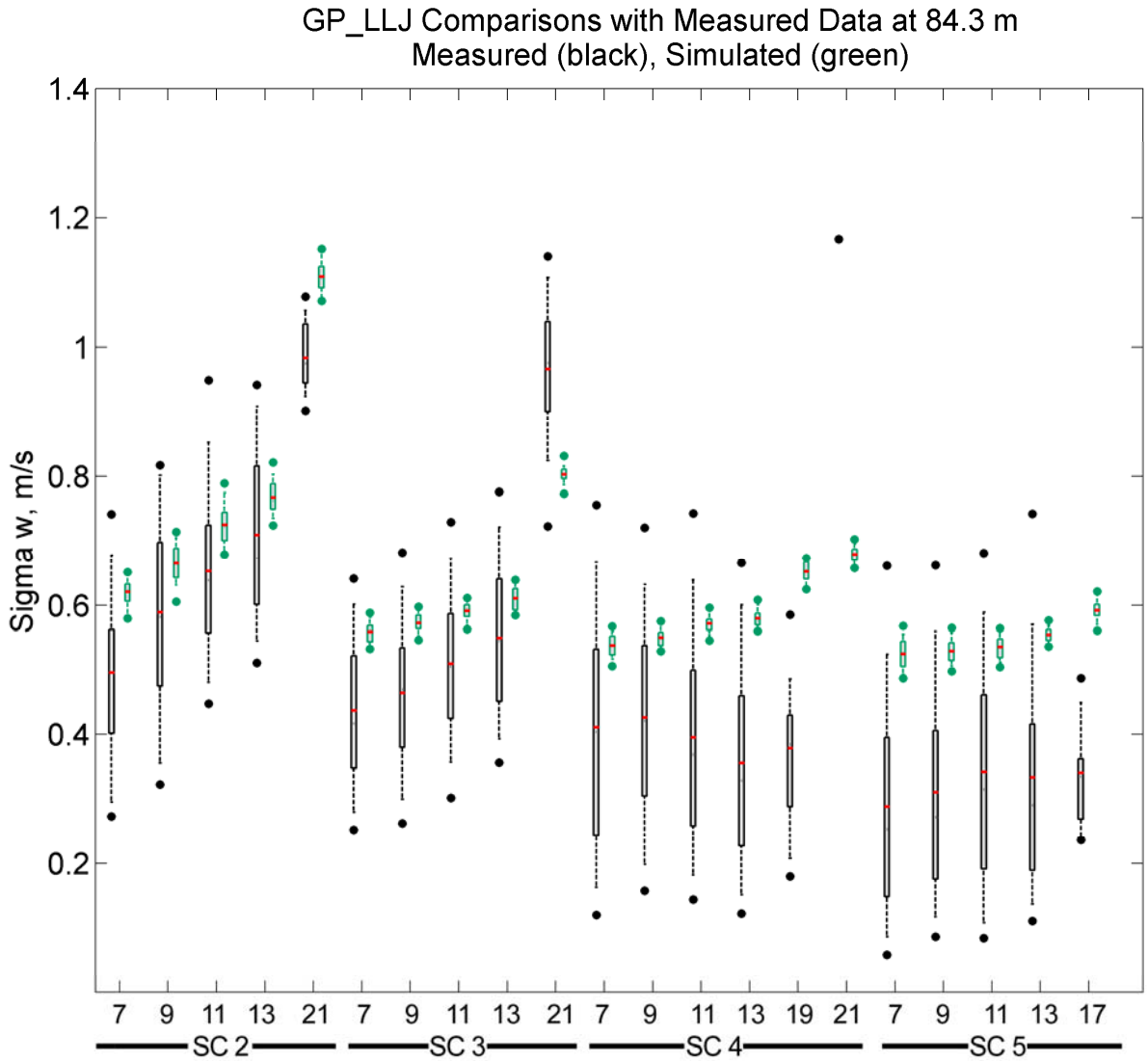
GP_LLJ vs. Lamar: Sigma u



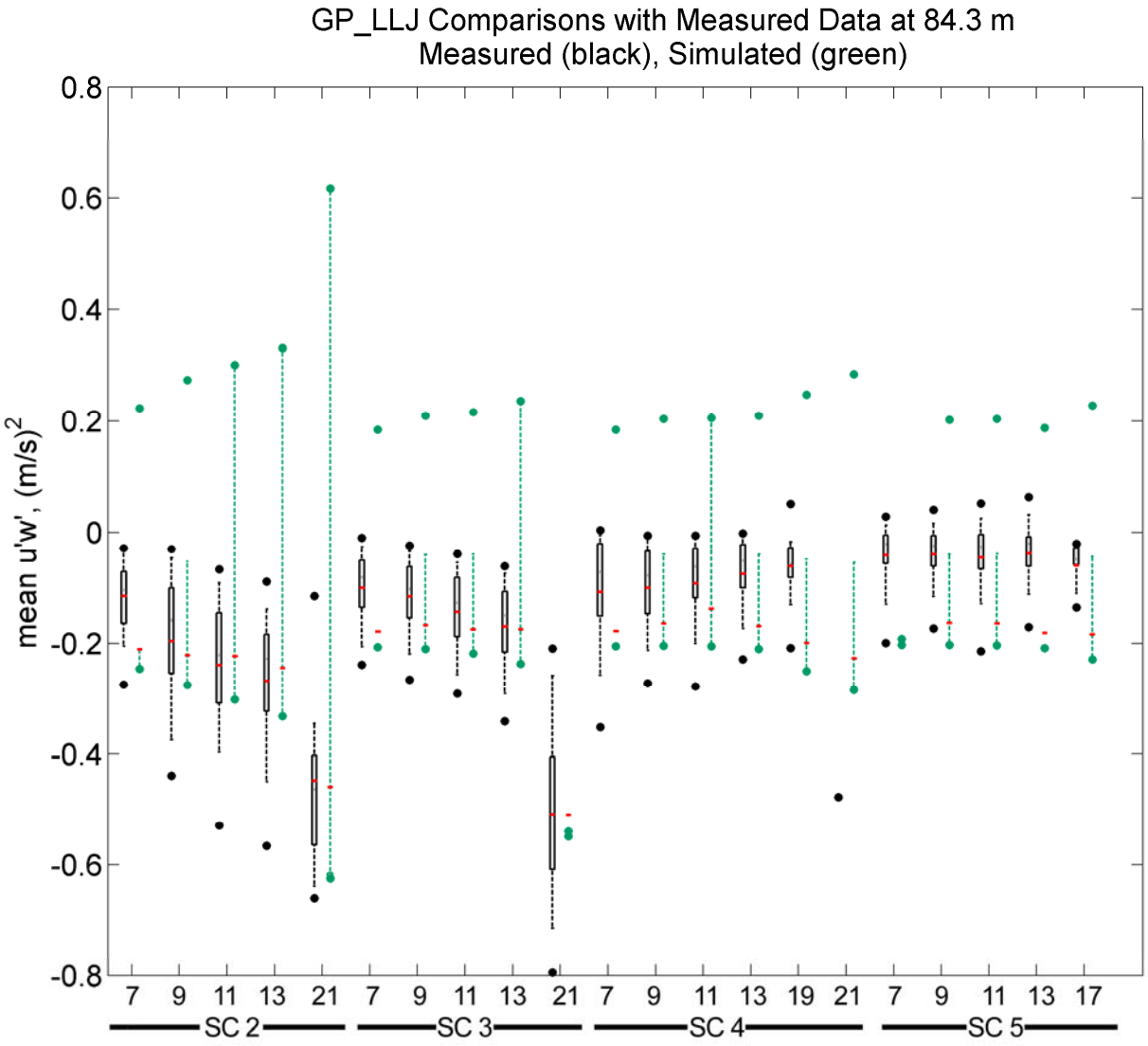
GP_LLJ vs. Lamar: Sigma v



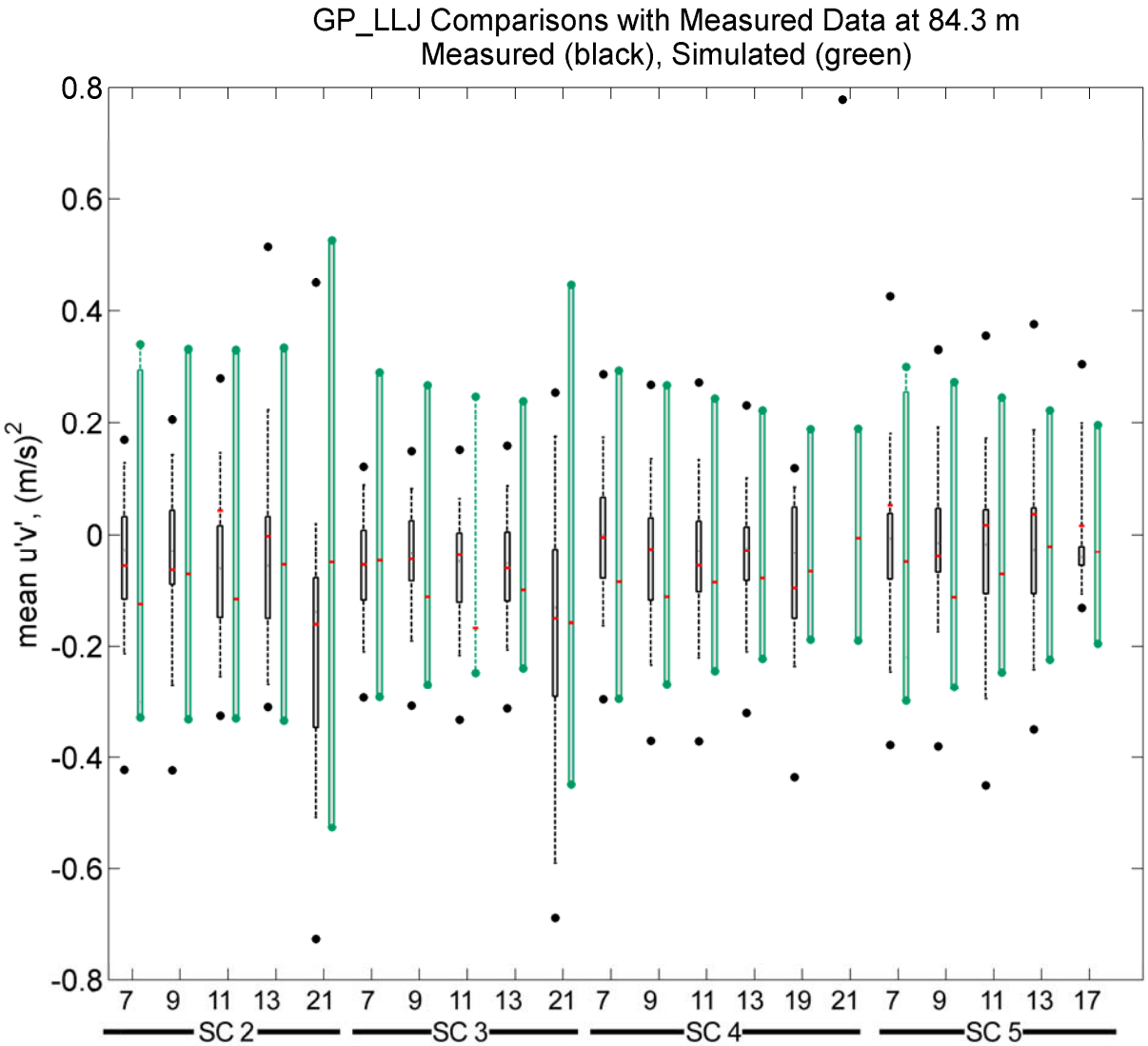
GP_LLJ vs. Lamar: Sigma w



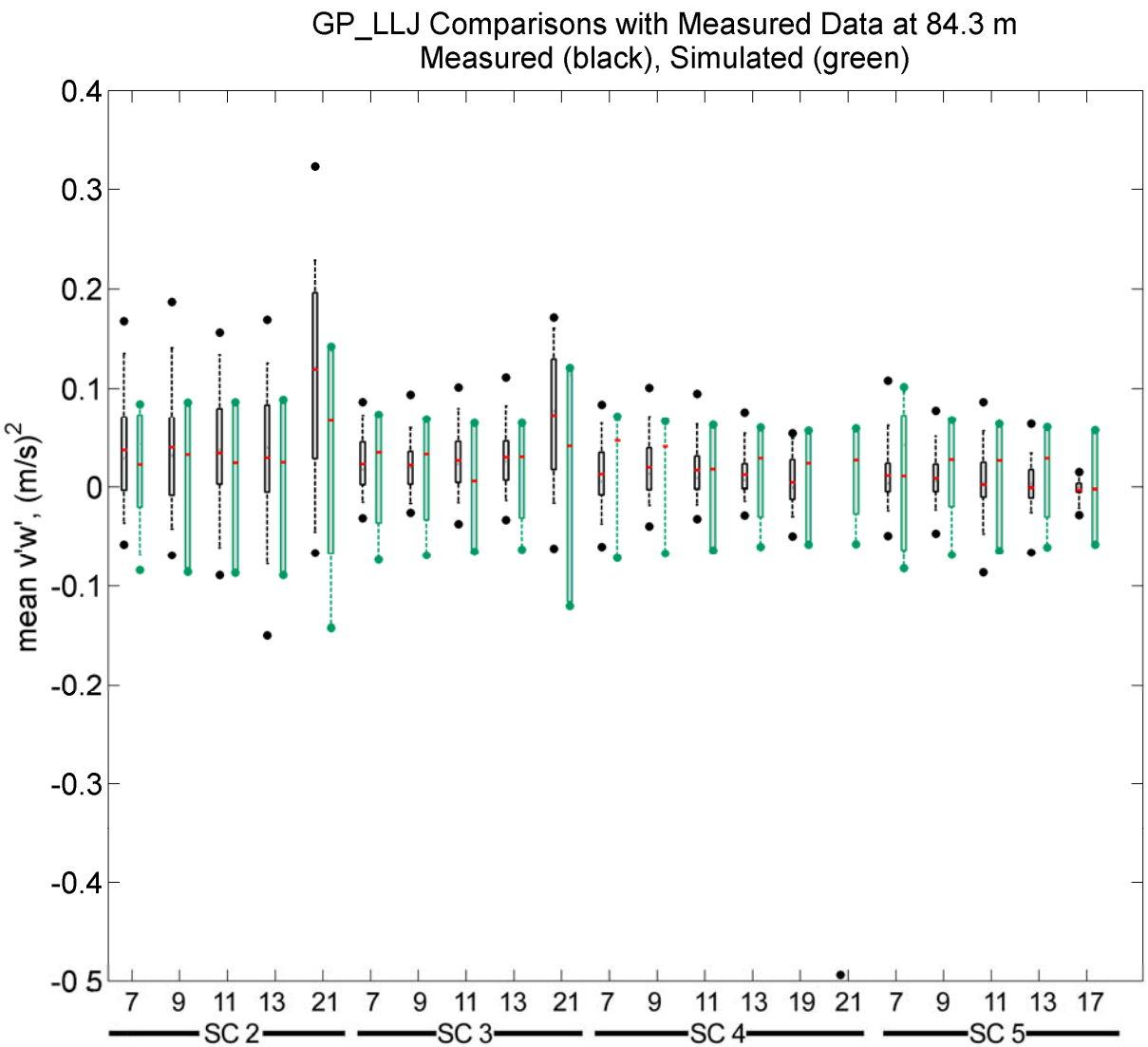
GP_LLJ vs. Lamar: Mean u'w'



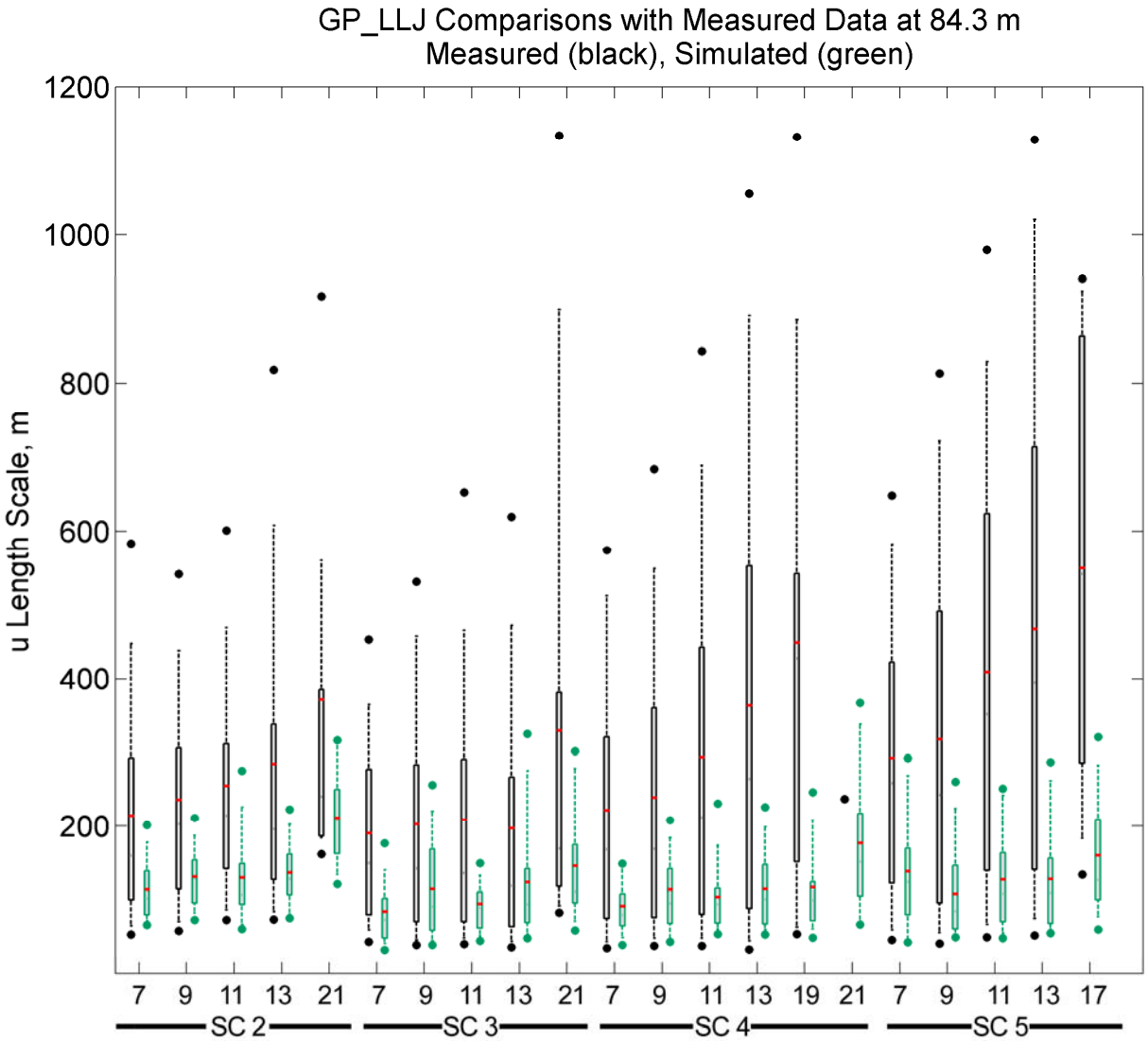
GP_LLJ vs. Lamar: Mean u'v'



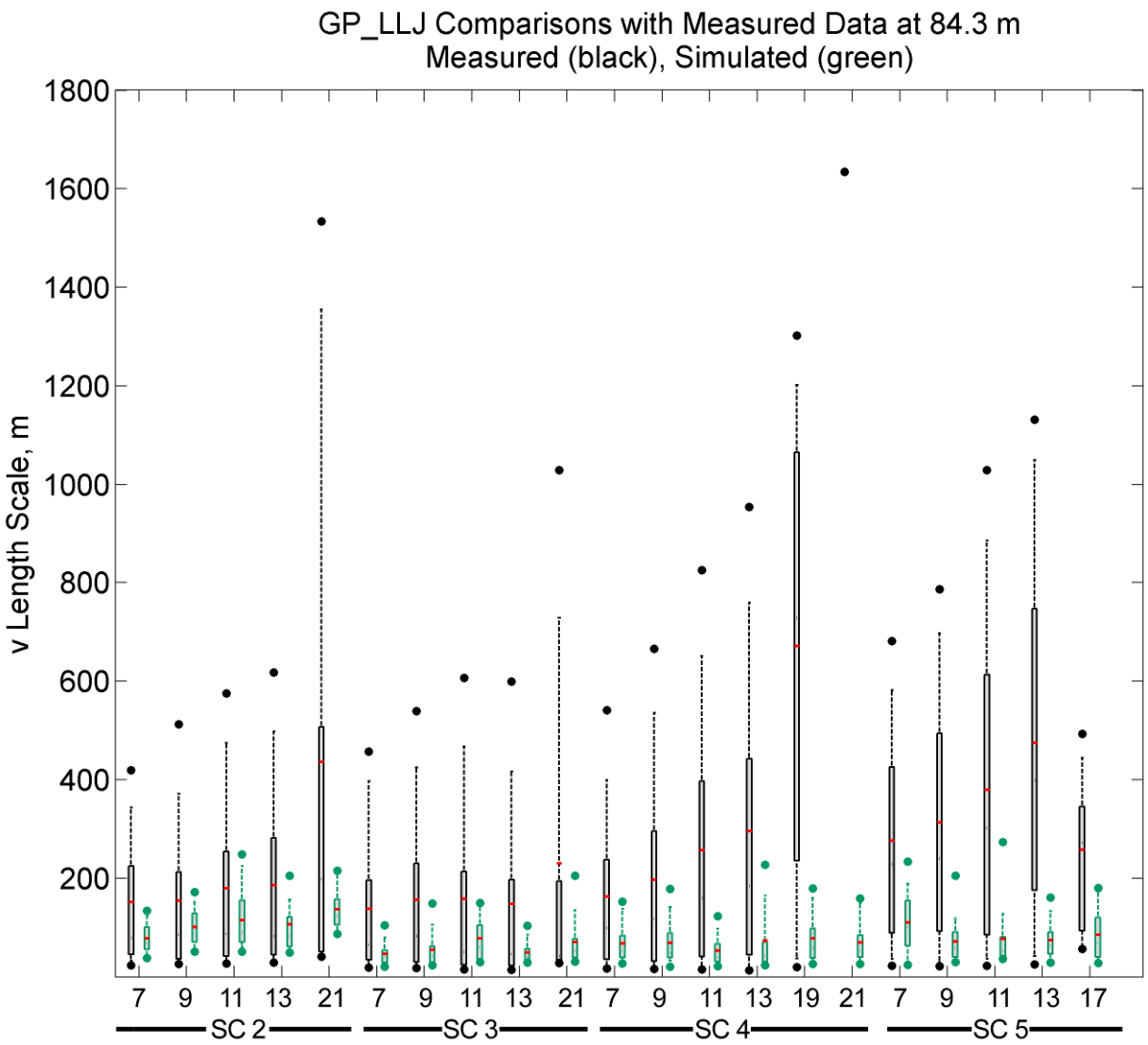
GP_LLJ vs. Lamar: Mean v'w'



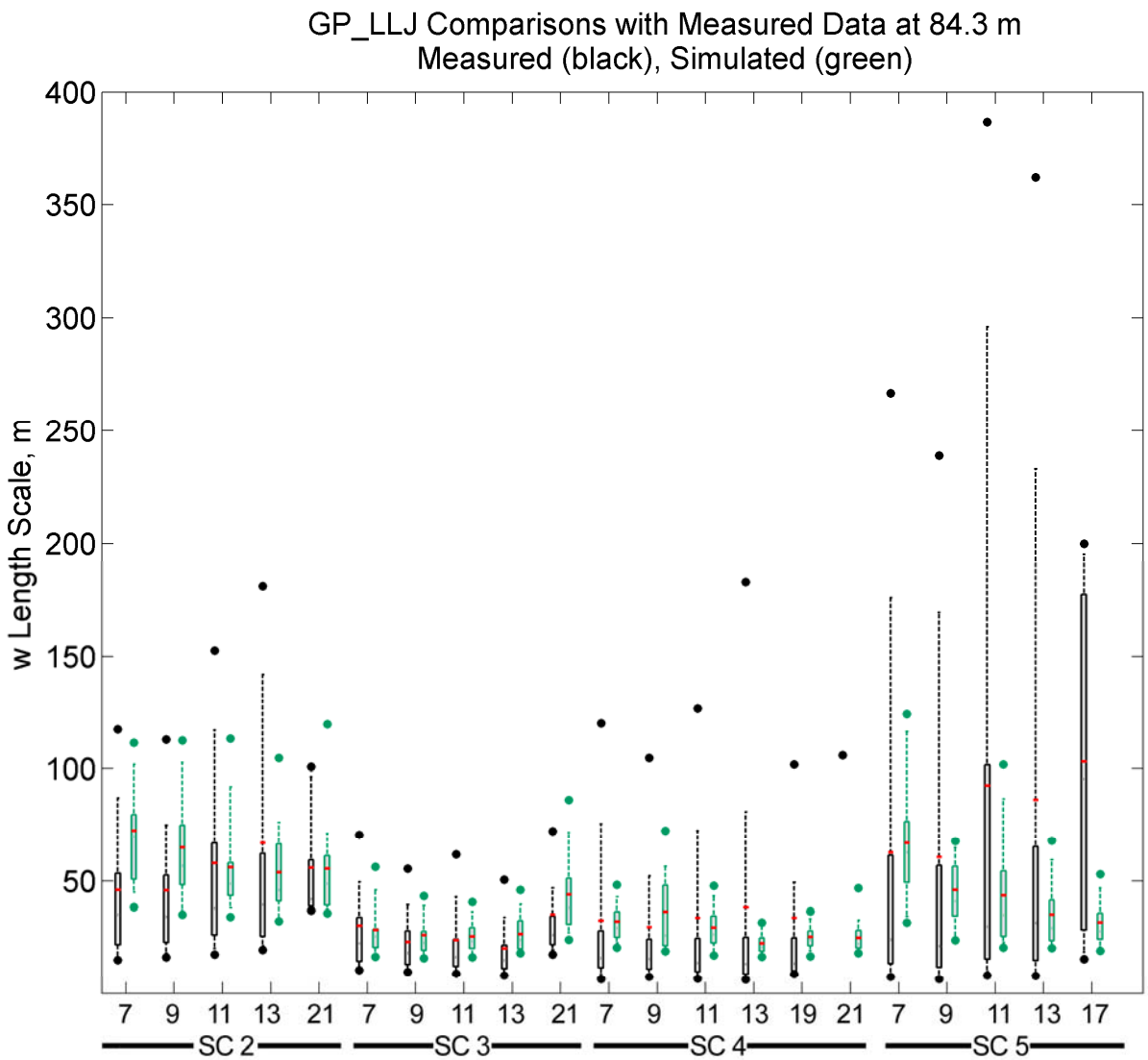
GP_LLJ vs. Lamar: L_u



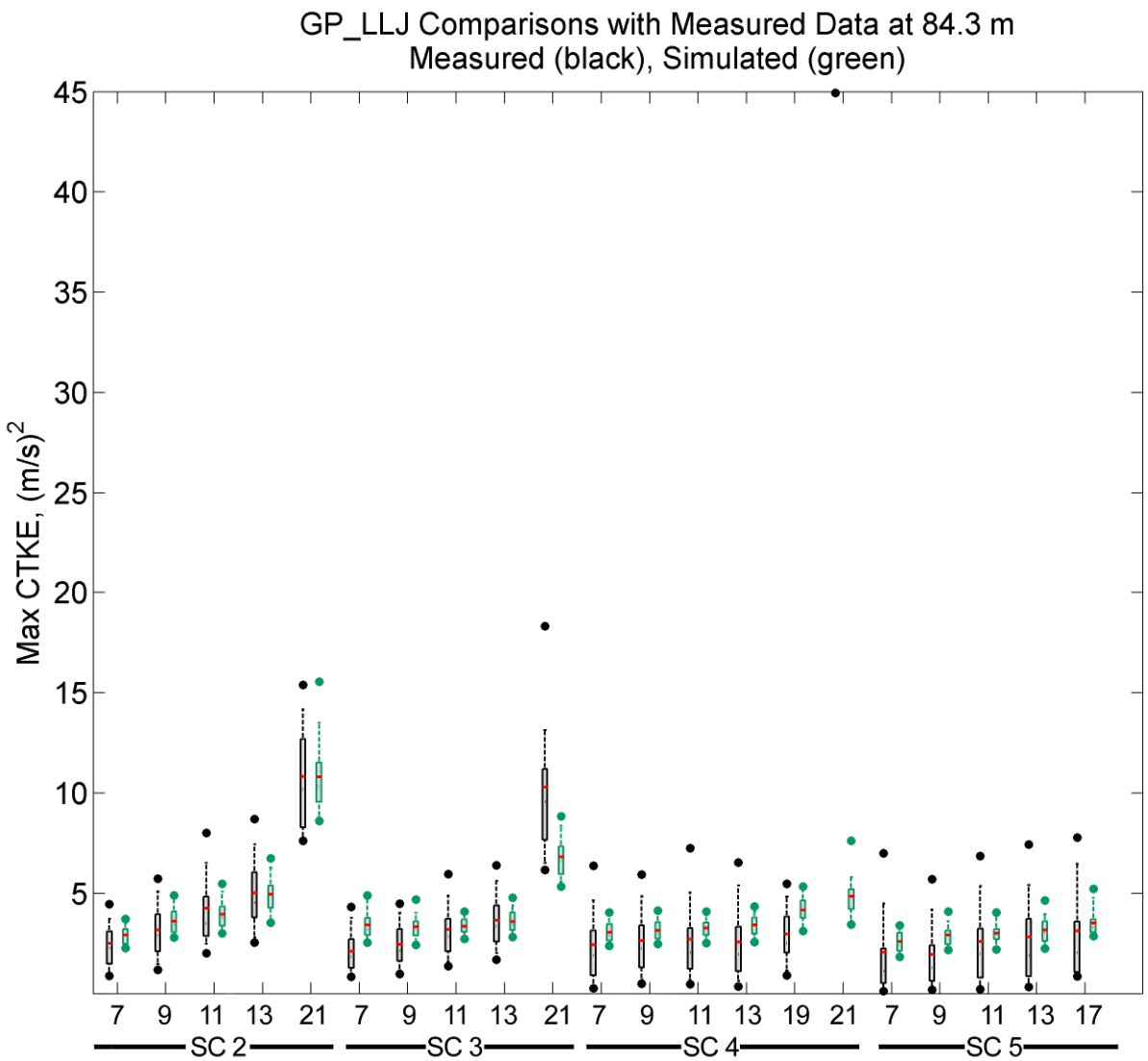
GP_LLJ vs. Lamar: L_v



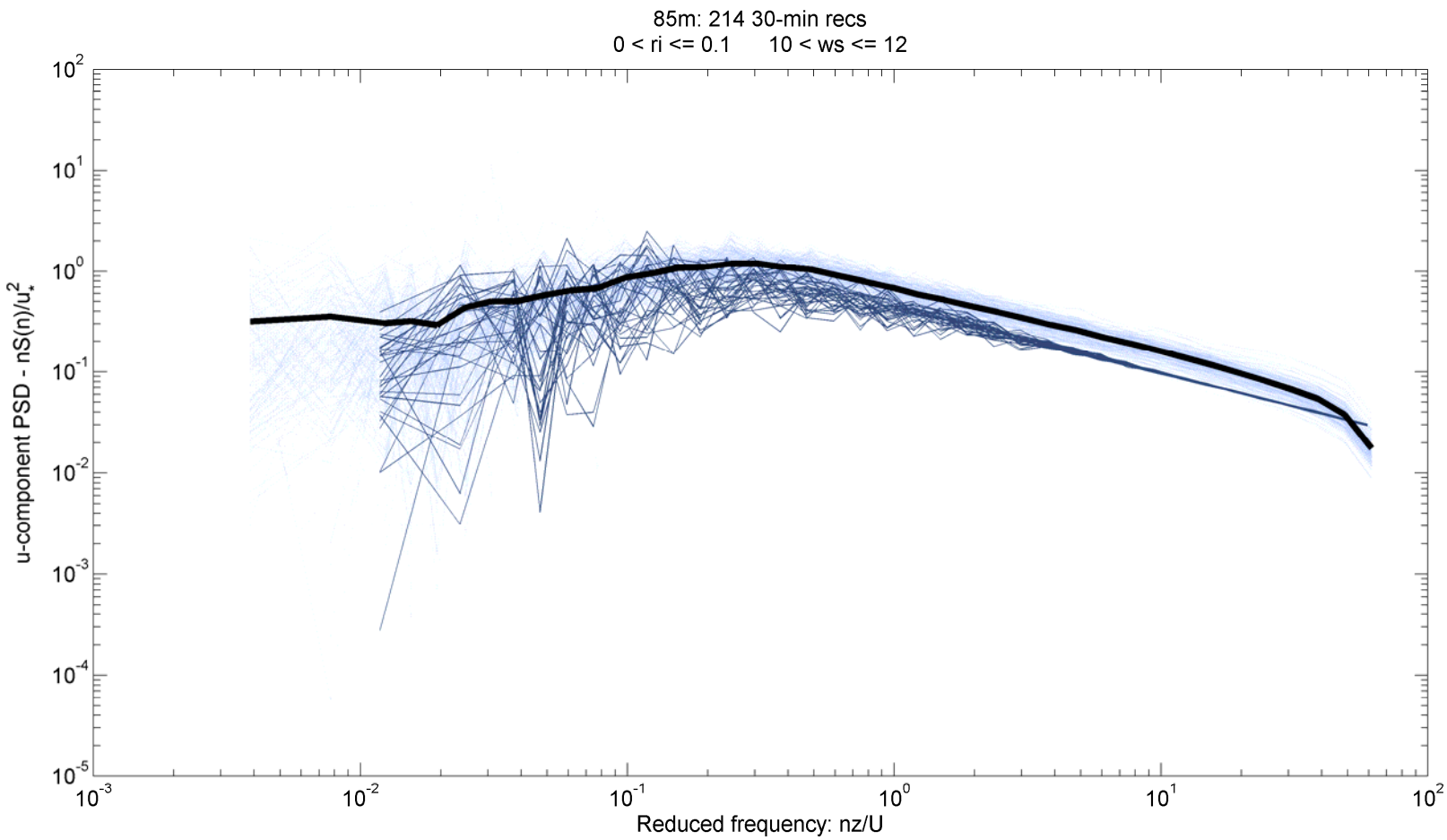
GP_LLJ vs. Lamar: L_w



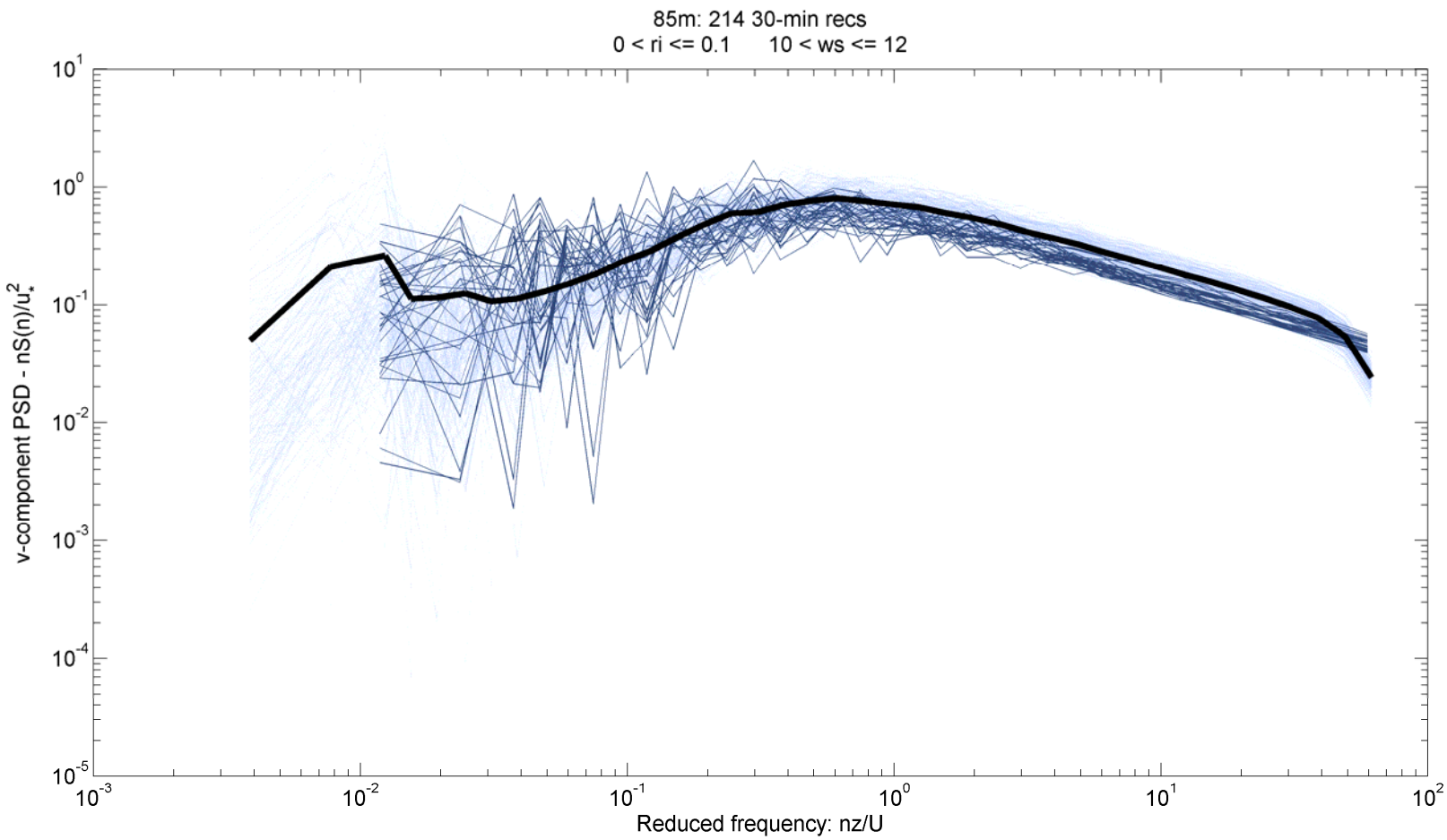
GP_LLJ vs. Lamar: Max CTKE



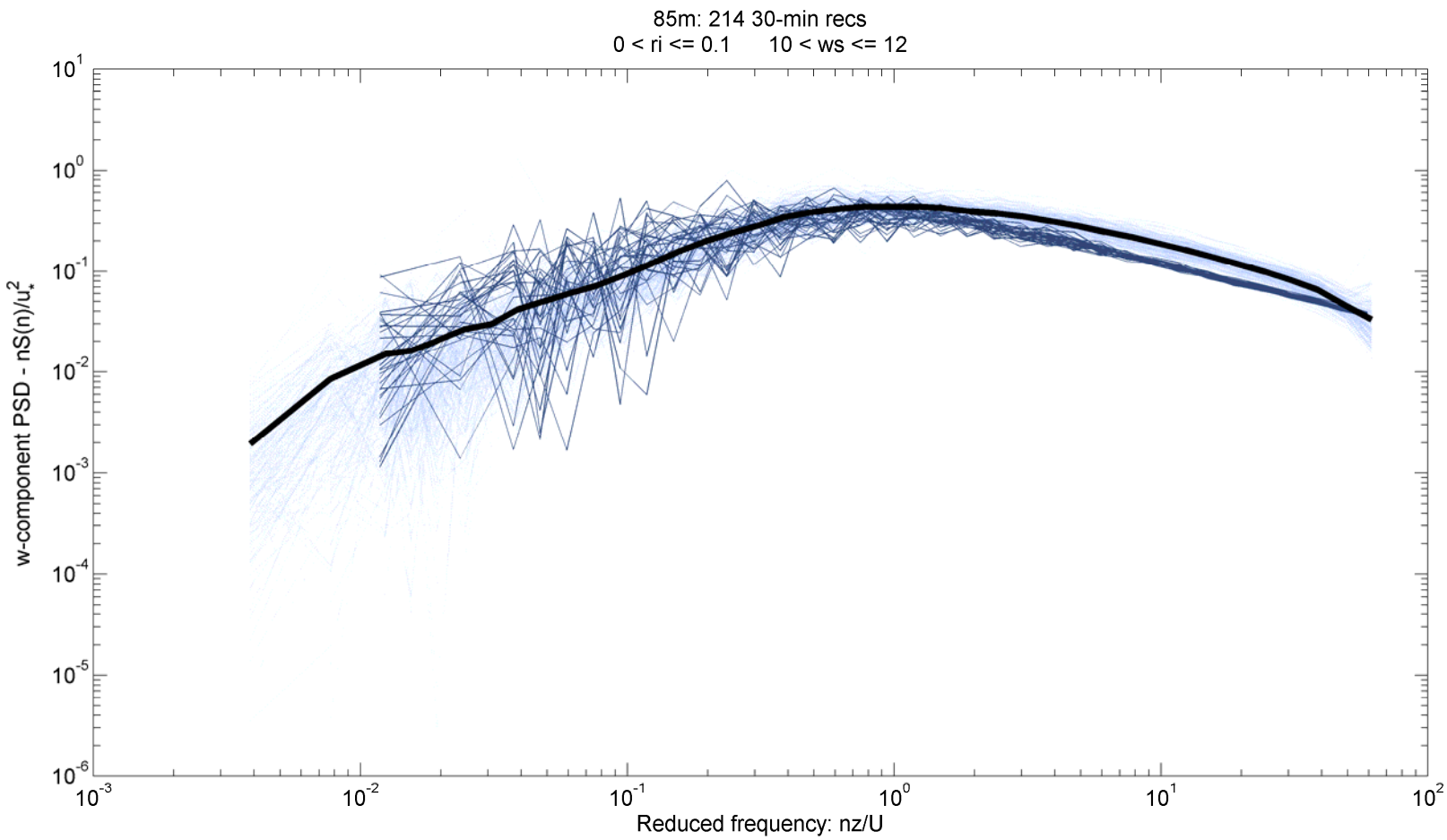
GP_LLJ vs. Lamar: Spectra



GP_LLJ vs. Lamar: Spectra



GP_LLJ vs. Lamar: Spectra

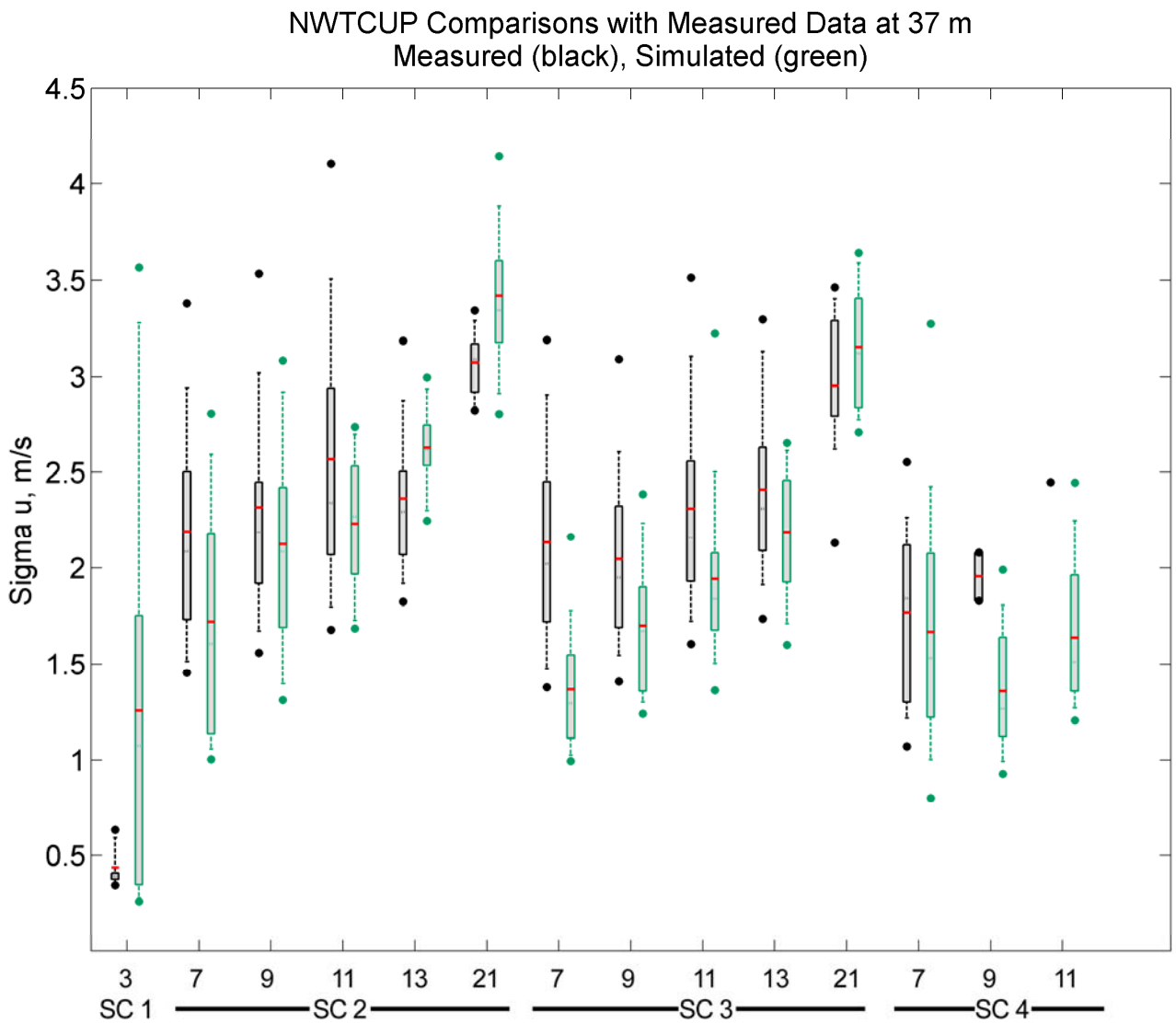


NWTCUP Model vs. NWTC/LIST Data

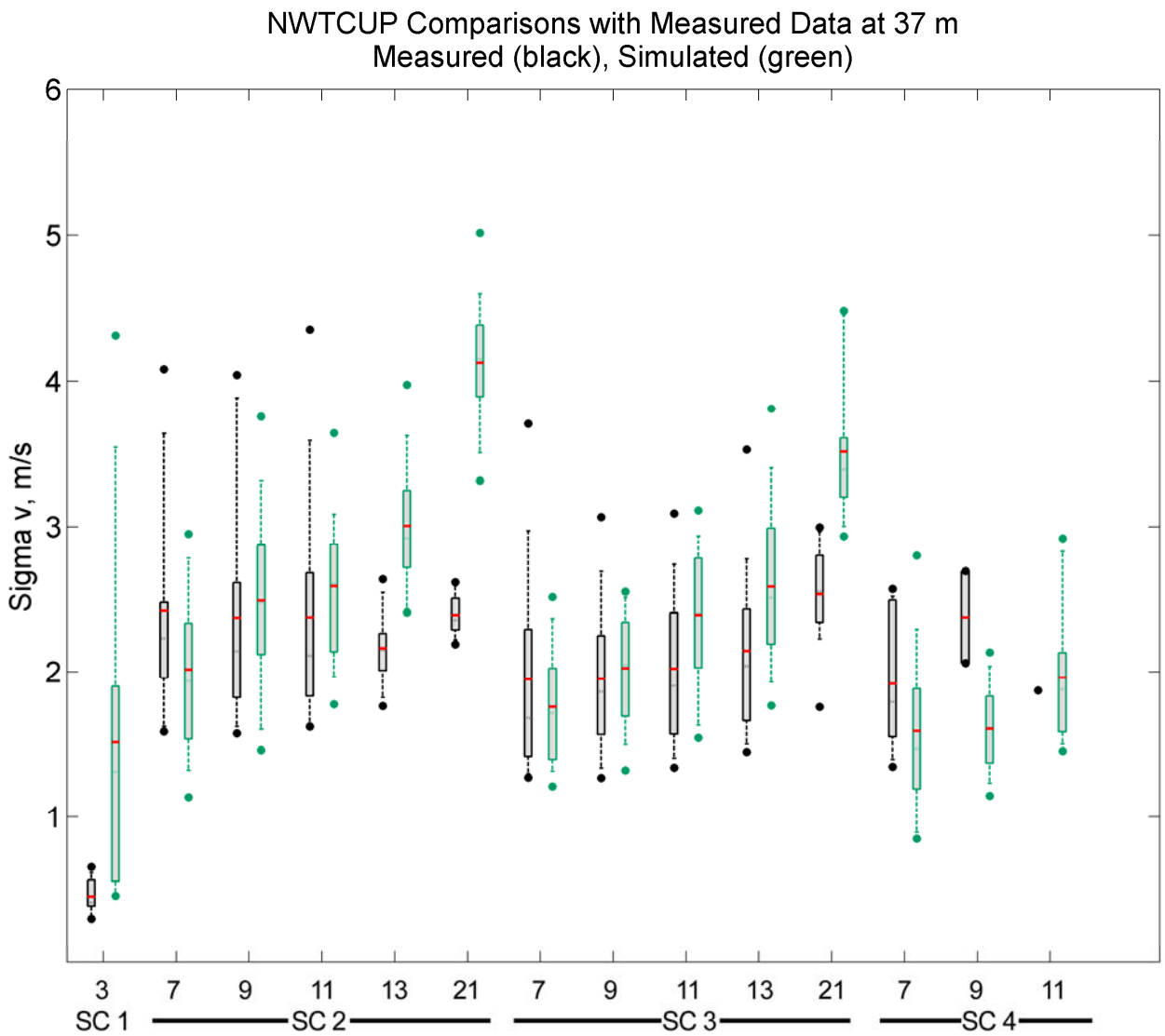
- 14 cases, 31 random seeds each
- 25x25 grid
- 2.1-m grid spacing
- Comparisons at 37-m hub-height

Stability Category	Wind Speed Bins 3	5	7	9	11	13	15	17	19	21
1	N									
2			L N O	L N I O R	L N I O R	L N I O	O			L N I
3			L N O	L N I O R	L N I O R	L N I O R	O		I	L N
4			L N O	L N R	L N R	L			L	L
5			L	L	L	L		L		

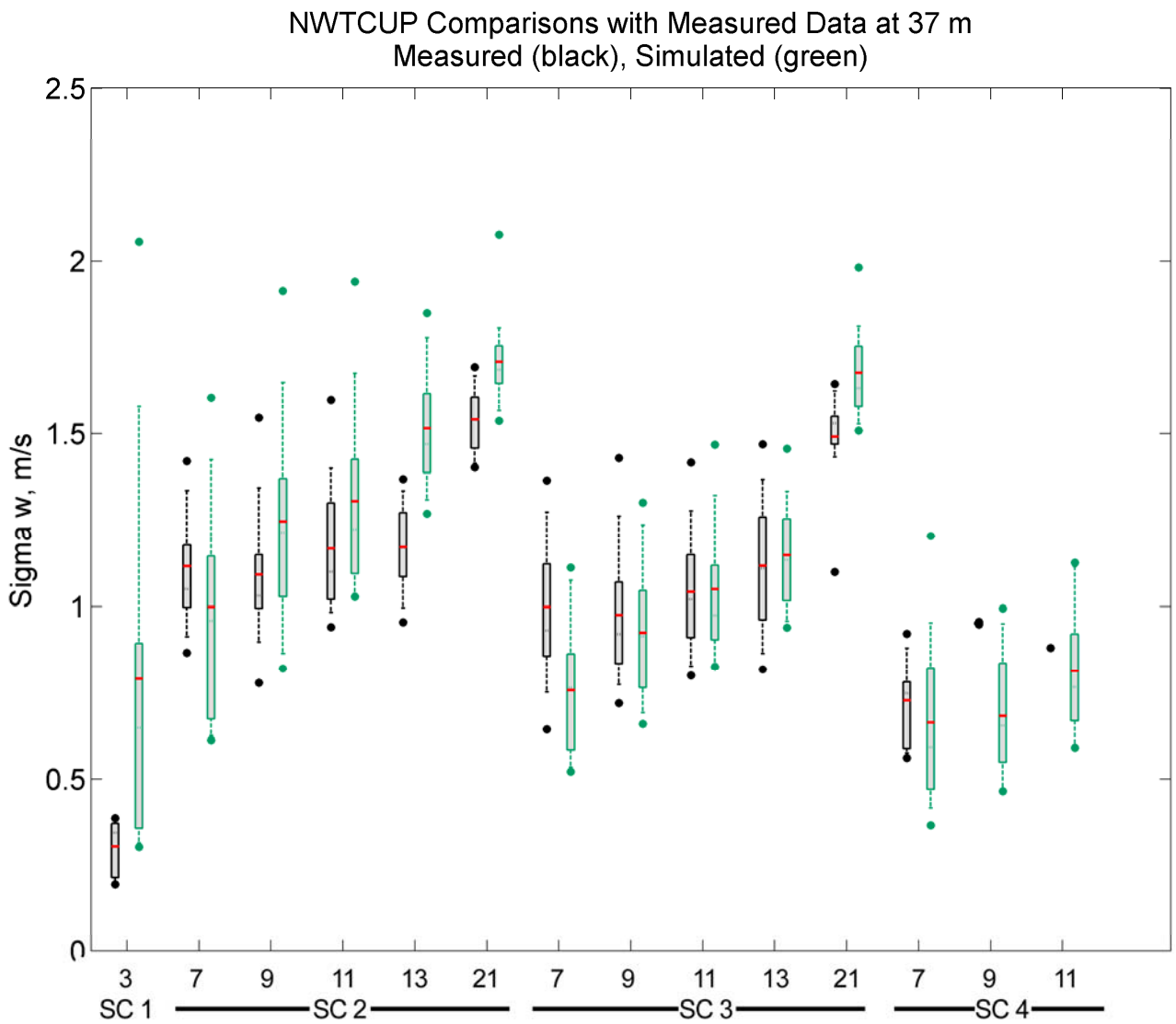
NWTCUP vs. NWTC/LIST: Sigma u



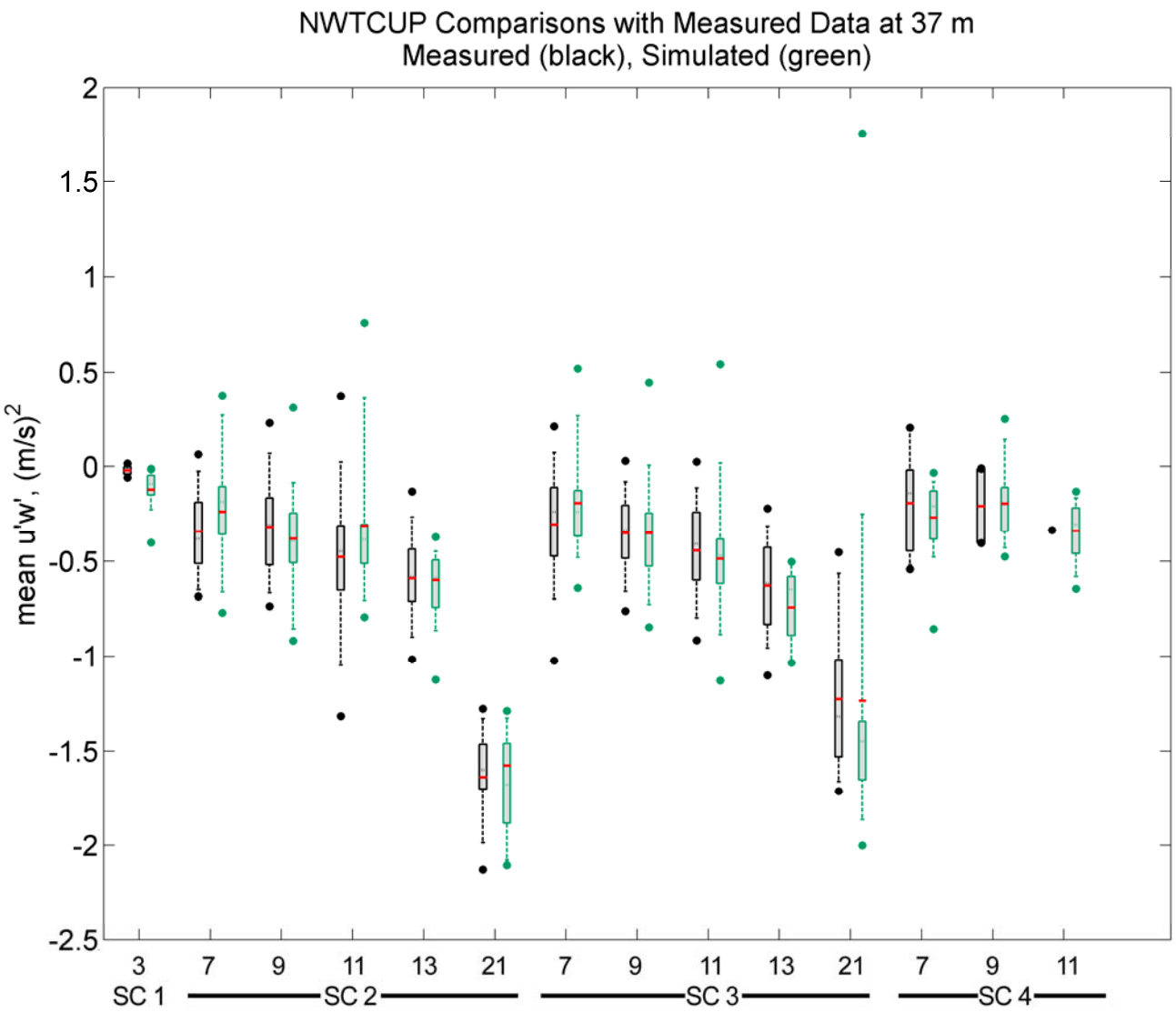
NWTCUP vs. NWTC/LIST: Sigma v



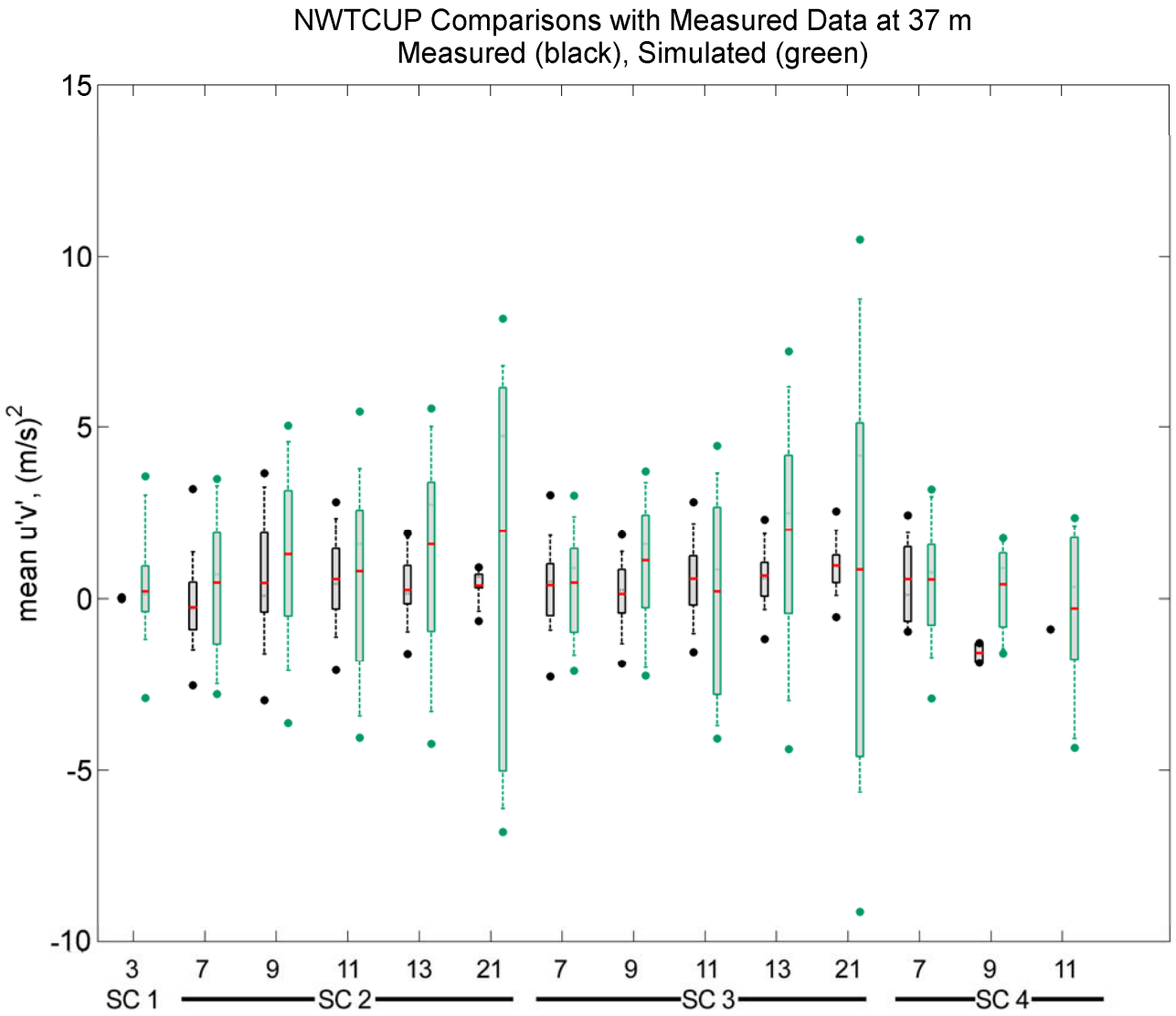
NWTCUP vs. NWTC/LIST: Sigma w



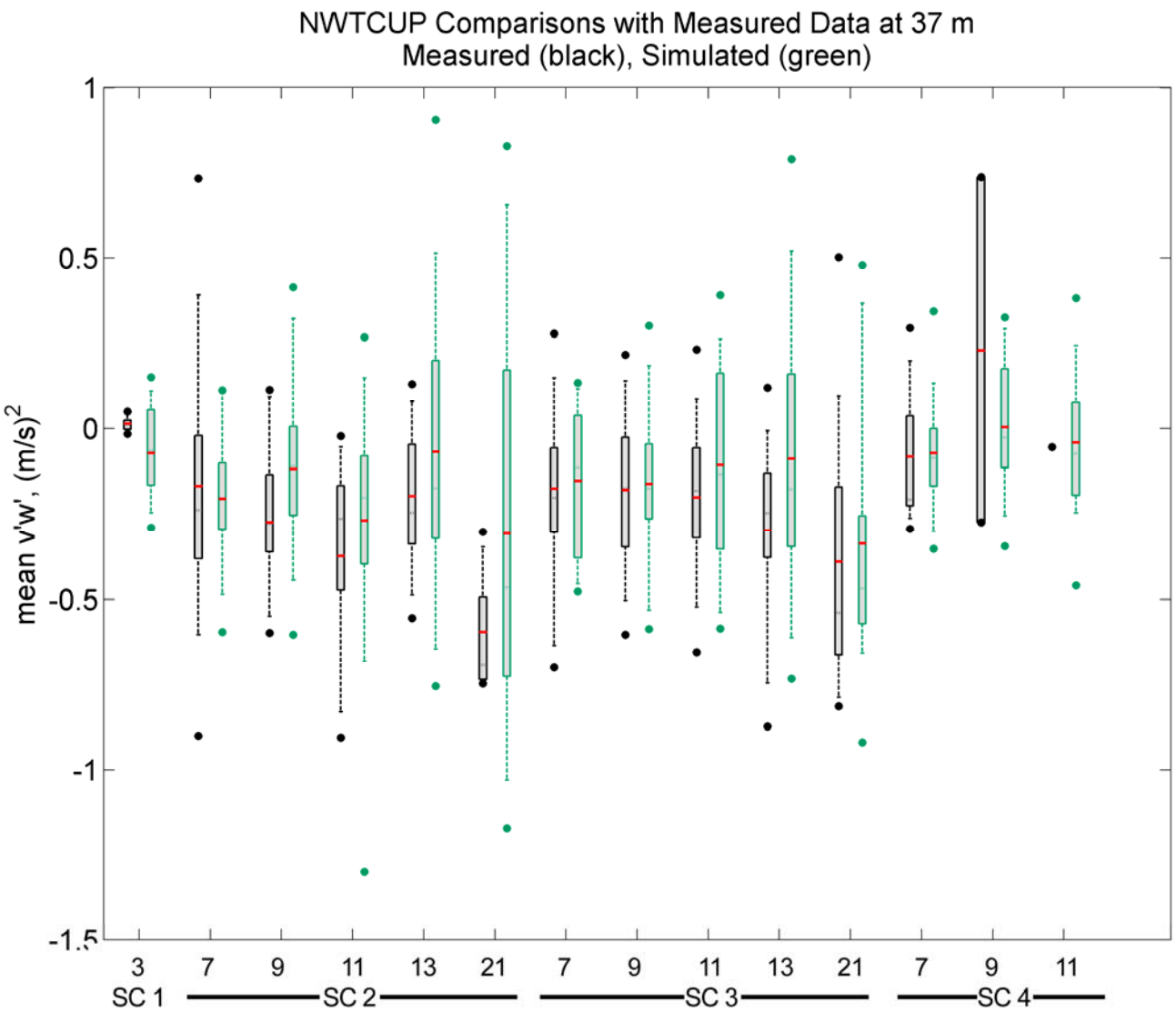
NWTCUP vs. NWTC/LIST: Mean u'w'



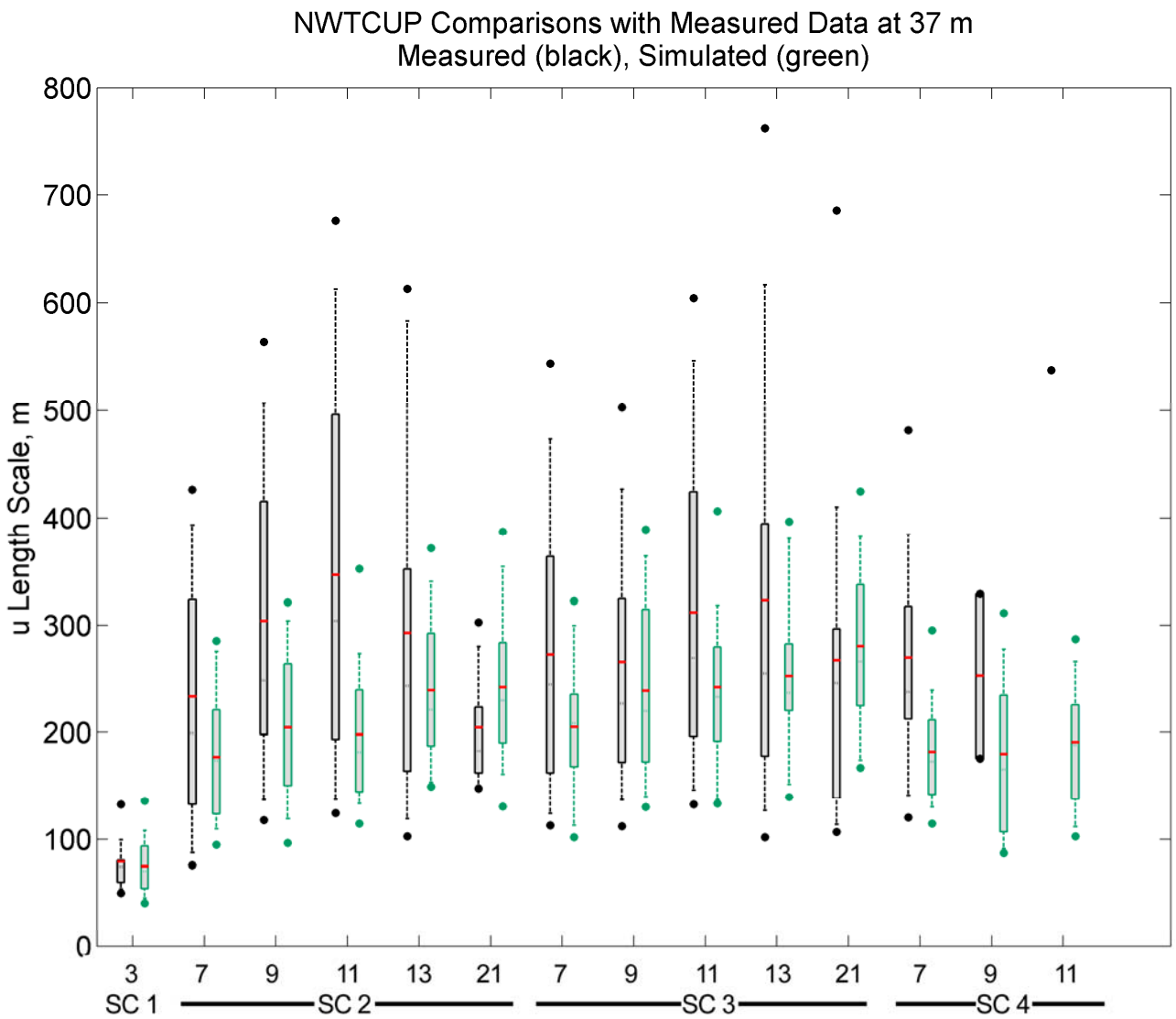
NWTCUP vs. NWTC/LIST: Mean u'v'



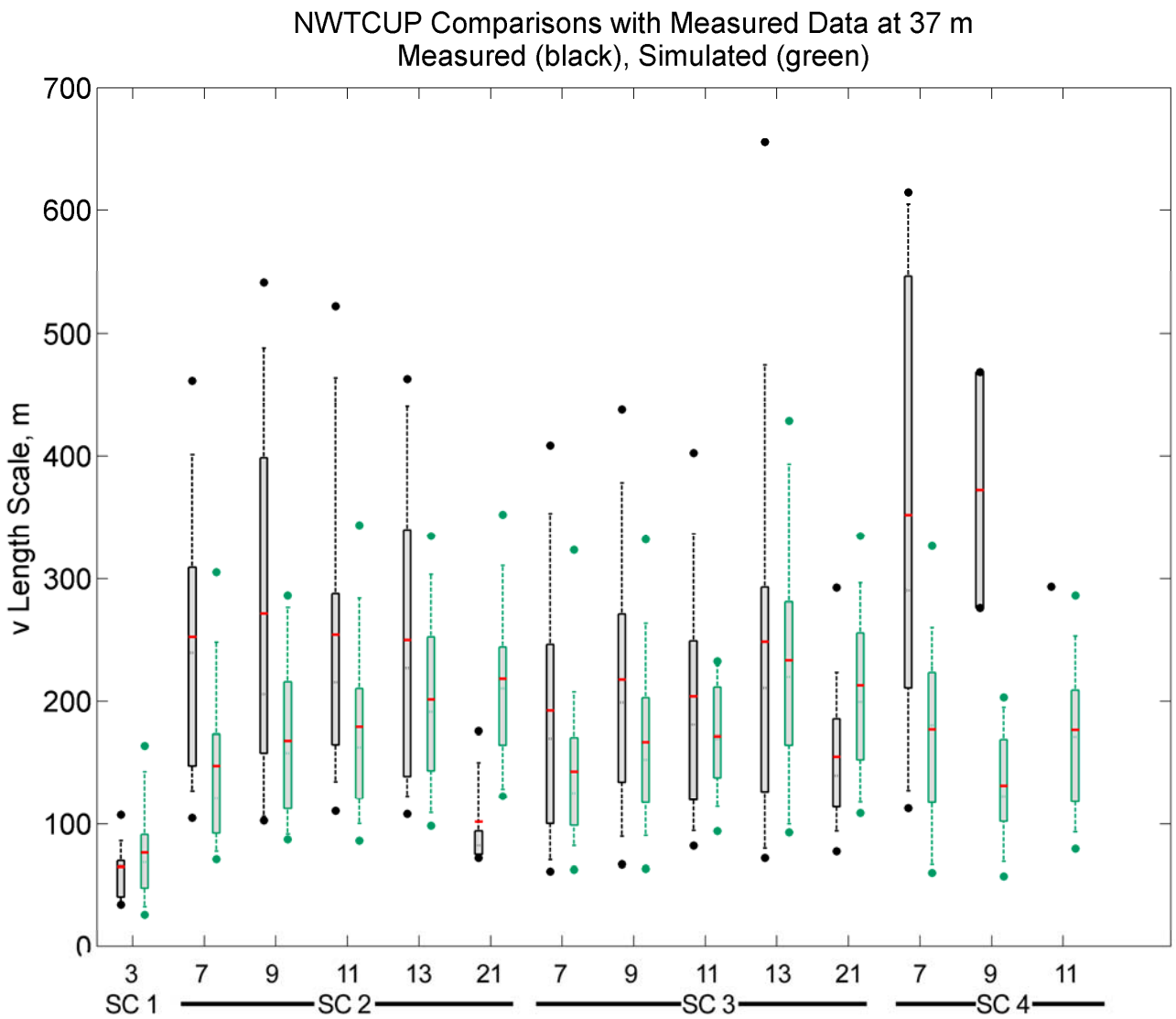
NWTCUP vs. NWTC/LIST: Mean v'w'



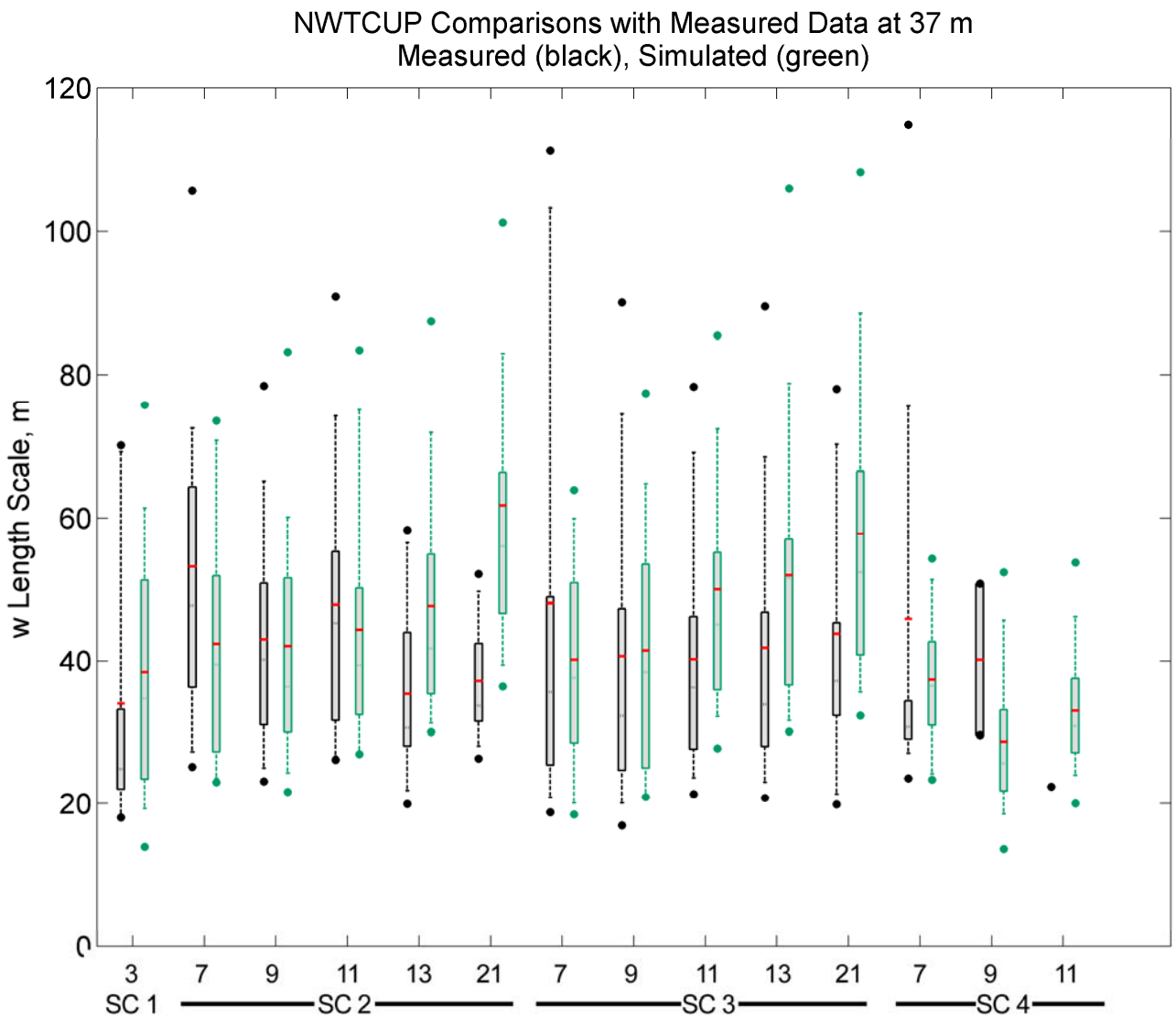
NWTCUP vs. NWTC/LIST: L_u



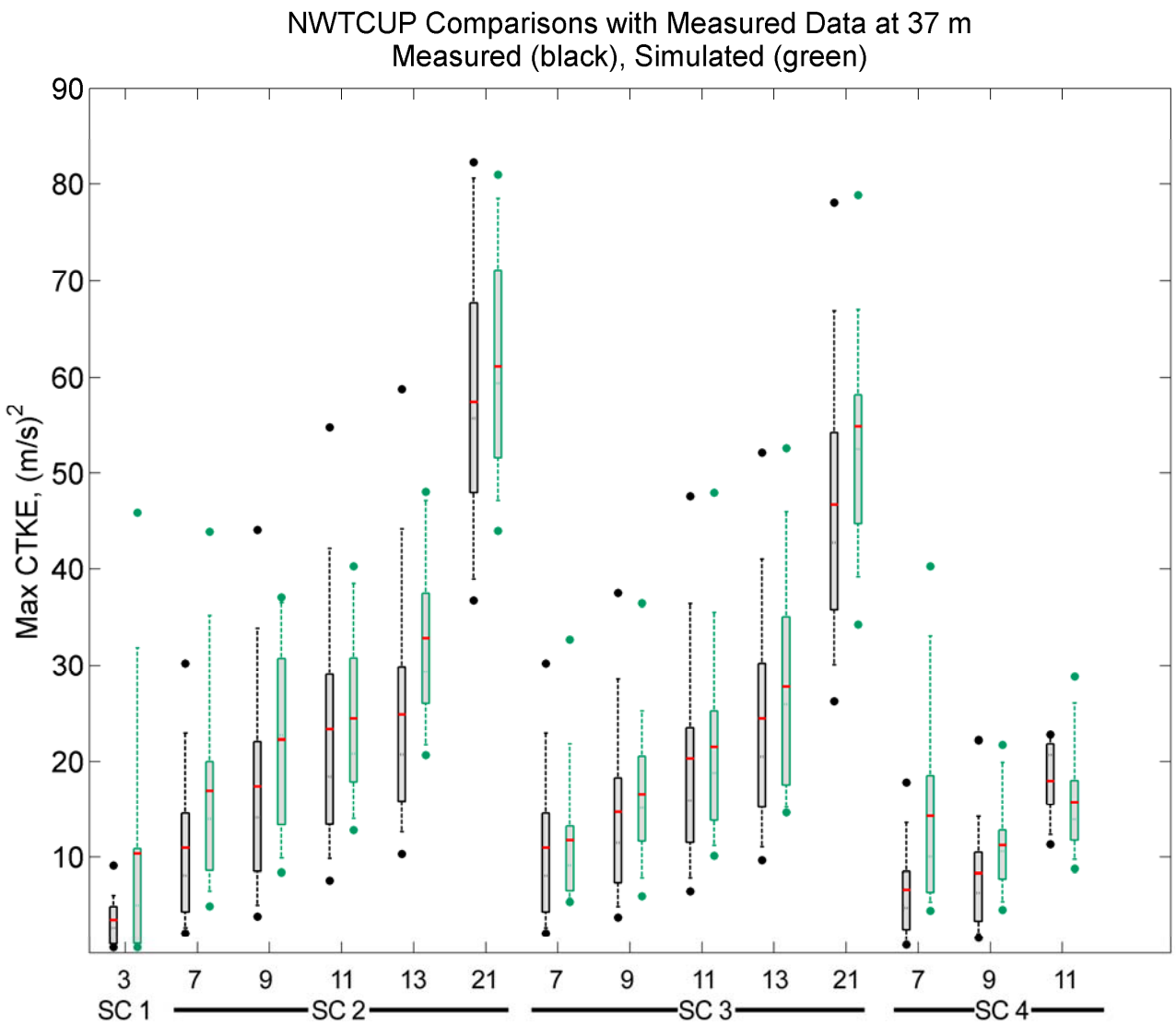
NWTCUP vs. NWTC/LIST: L_v



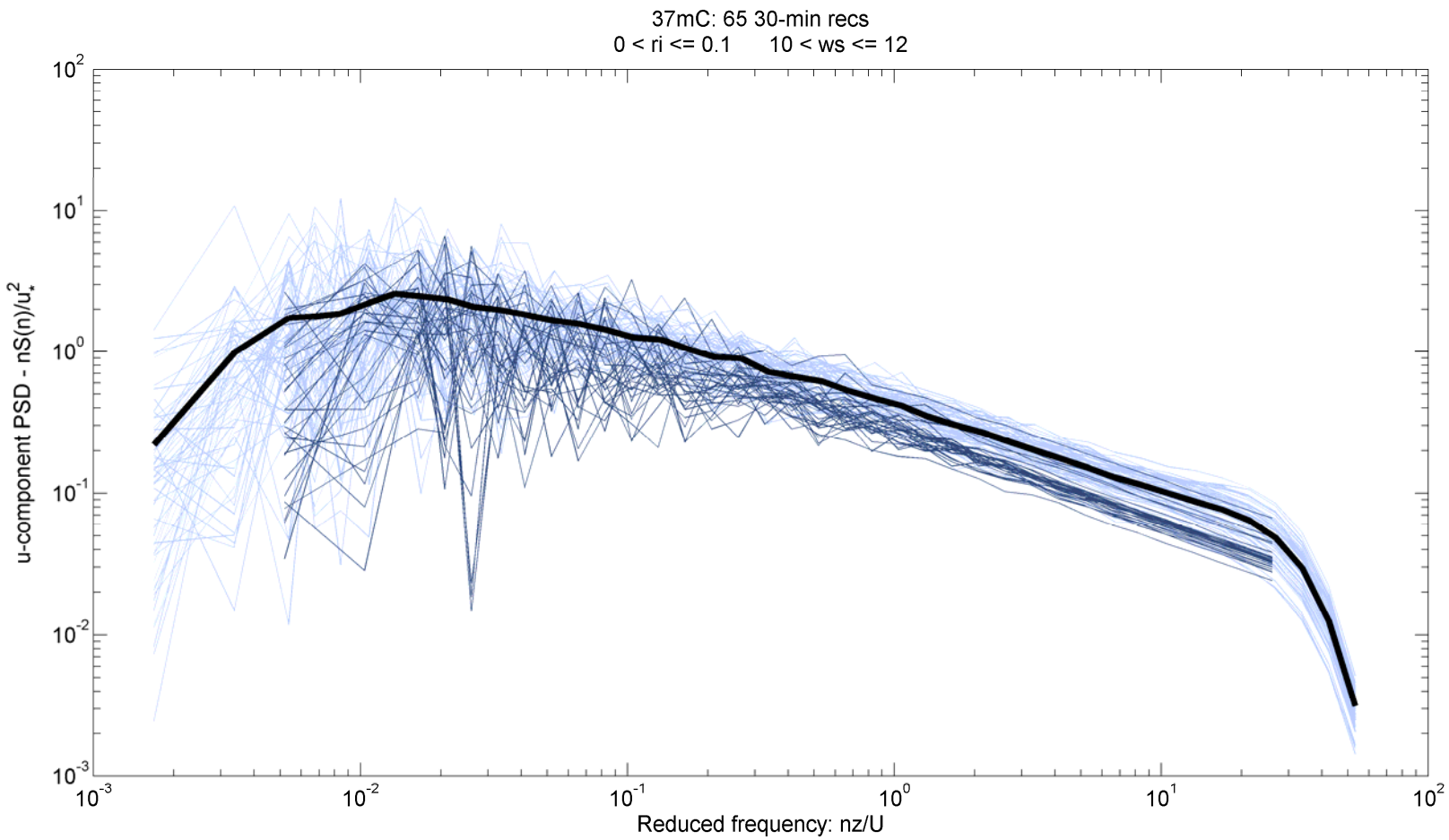
NWTCUP vs. NWTC/LIST: L_w



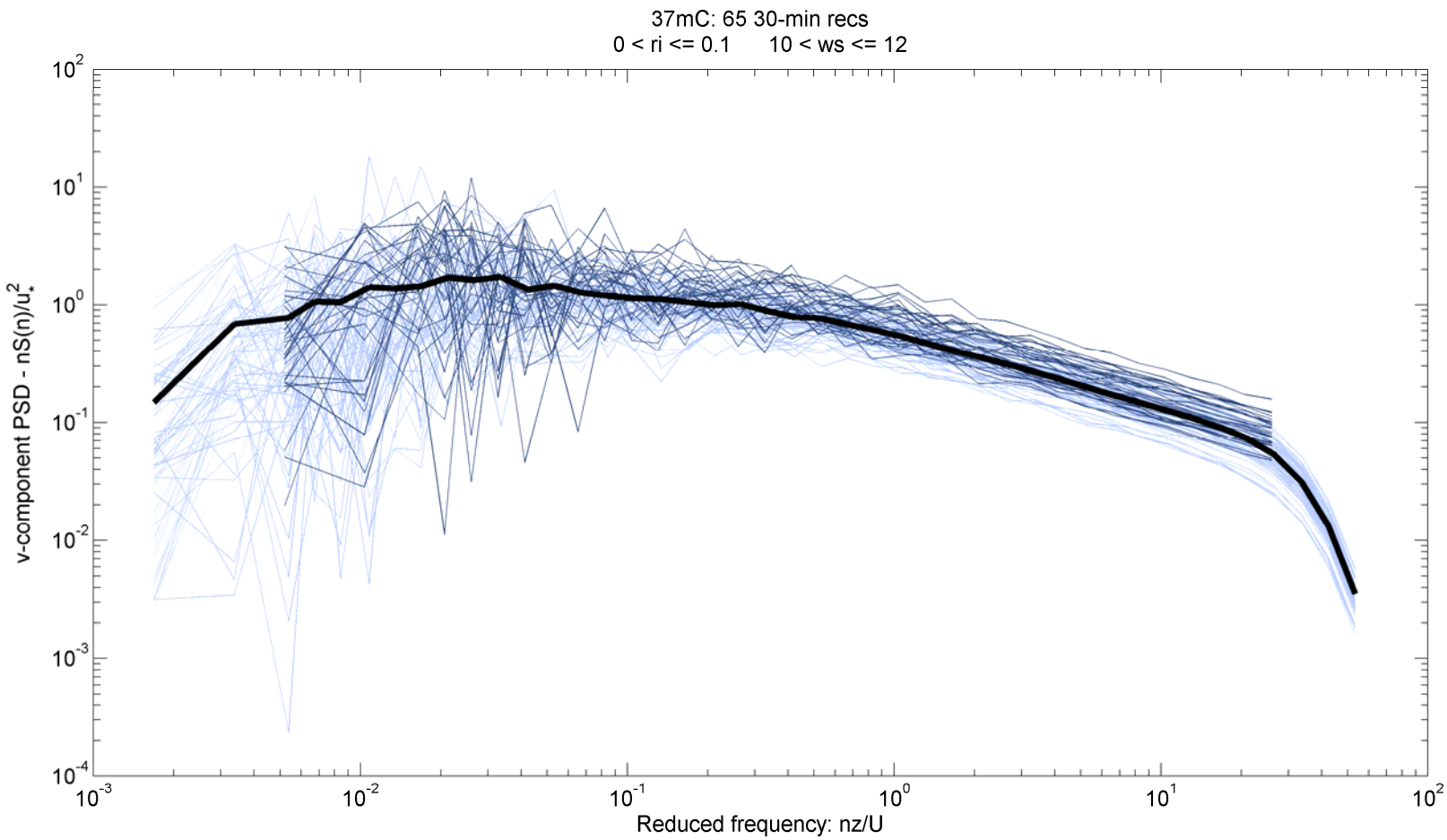
NWTCUP vs. NWTC/LIST: Max CTKE



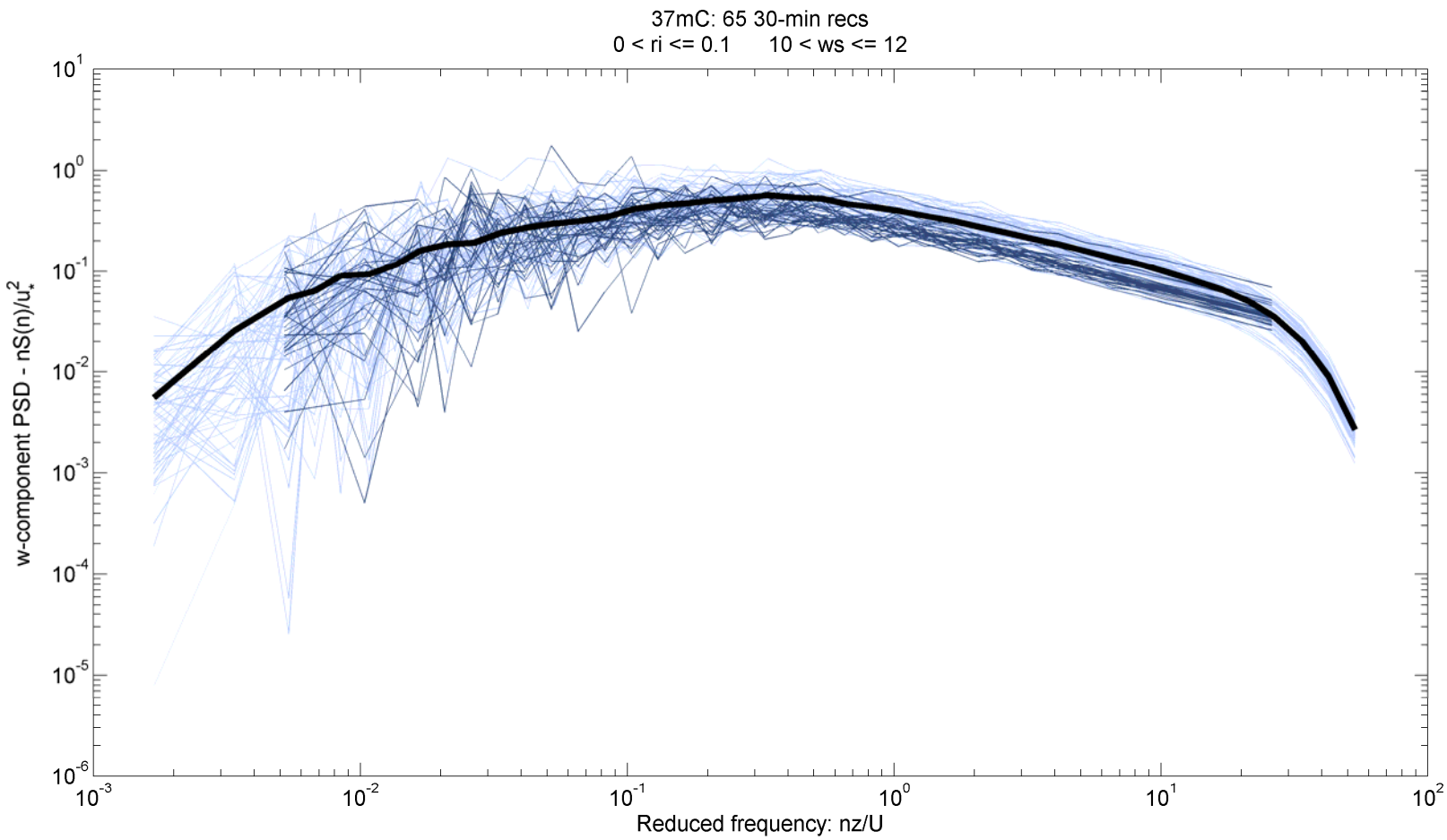
NWTCUP vs. NWTC/LIST: Spectra



NWTCUP vs. NWTC/LIST: Spectra



NWTCUP vs. NWTC/LIST: Spectra

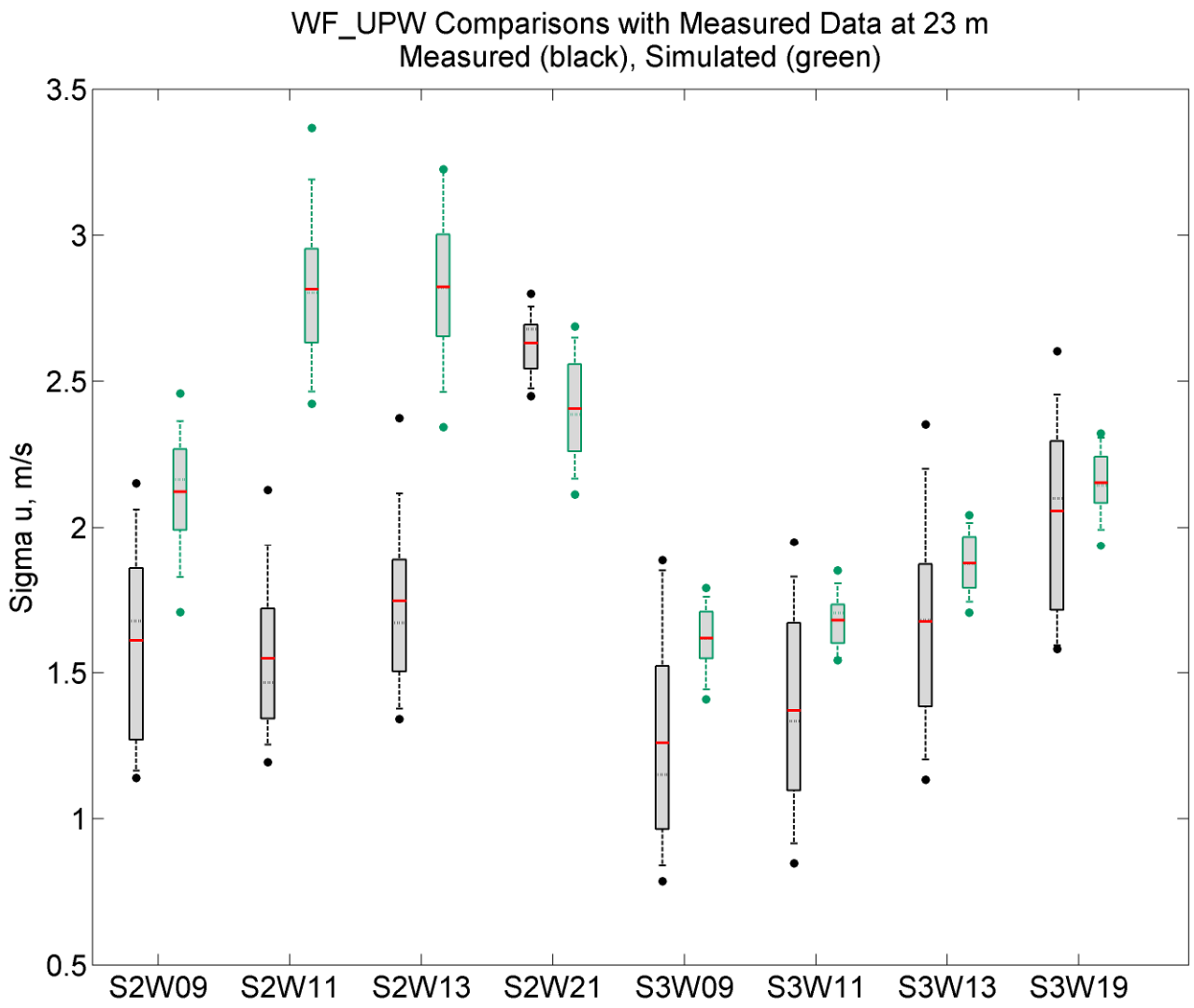


WF_UPW Model vs. San Gorgonio Inflow Data

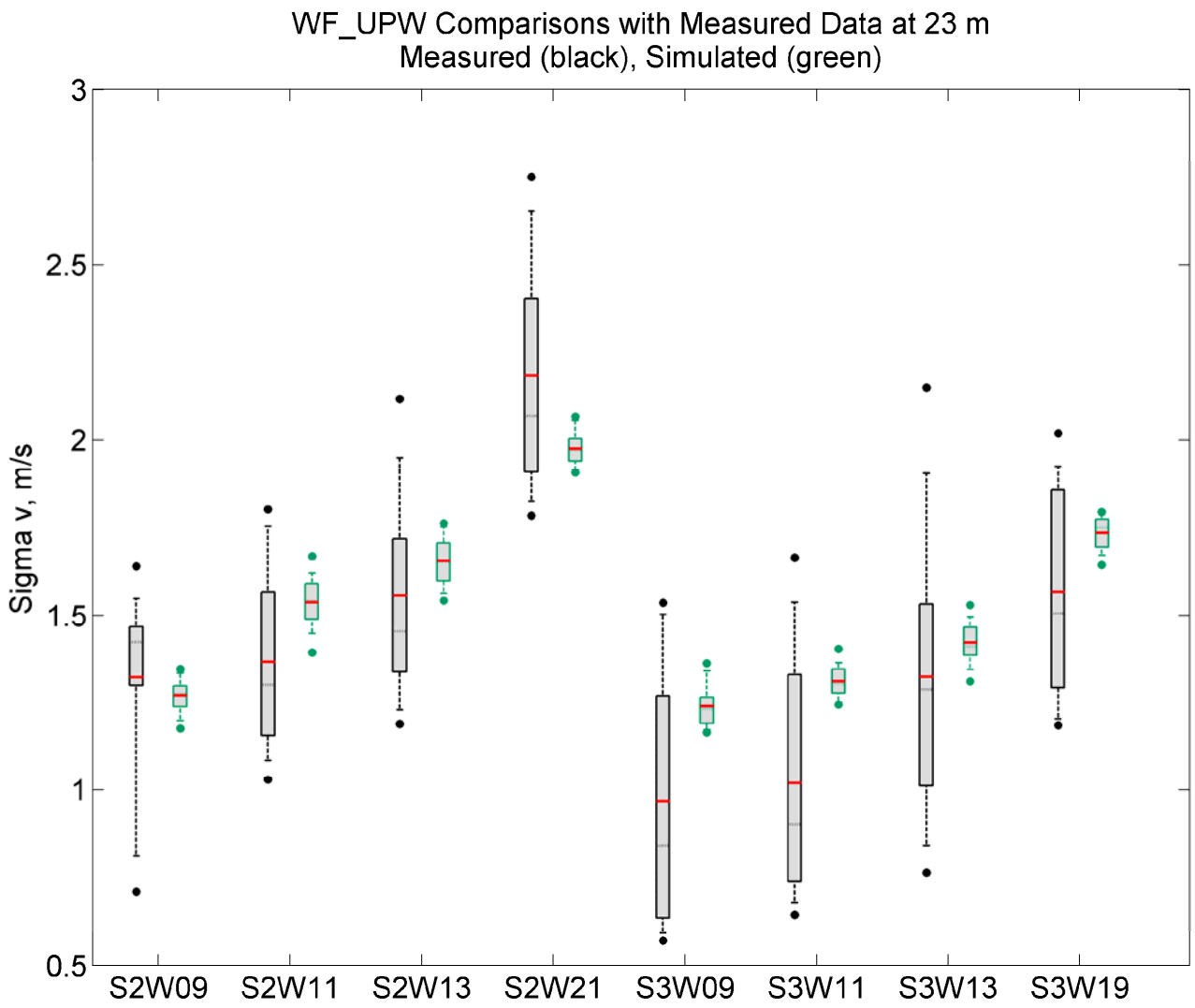
- 8 cases, 31 random seeds each
- 11x11 grid
- 2.3-m grid spacing
- Comparisons at 23-m hub-height

Stability Category	Wind Speed Bins 3	5	7	9	11	13	15	17	19	21
1	N									
2			L N O	L N I O R	L N I O R	L N I O	O			L N I
3			L N O	L N I O R	L N I O R	L N I O R	O		I	L N
4			L N O	L N R	L N R	L			L	L
5			L	L	L	L		L		

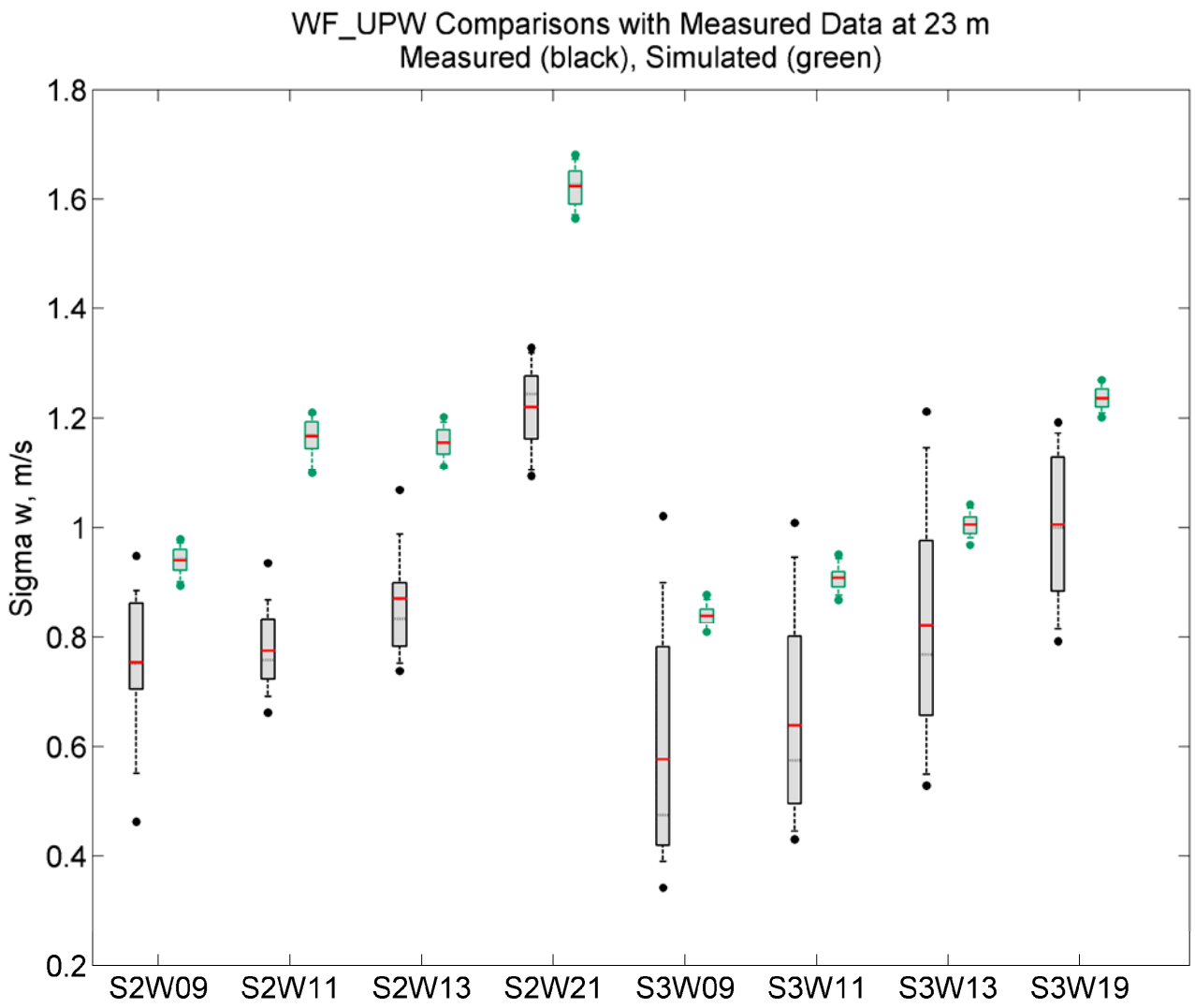
WF_UPW vs. Inflow: Sigma u



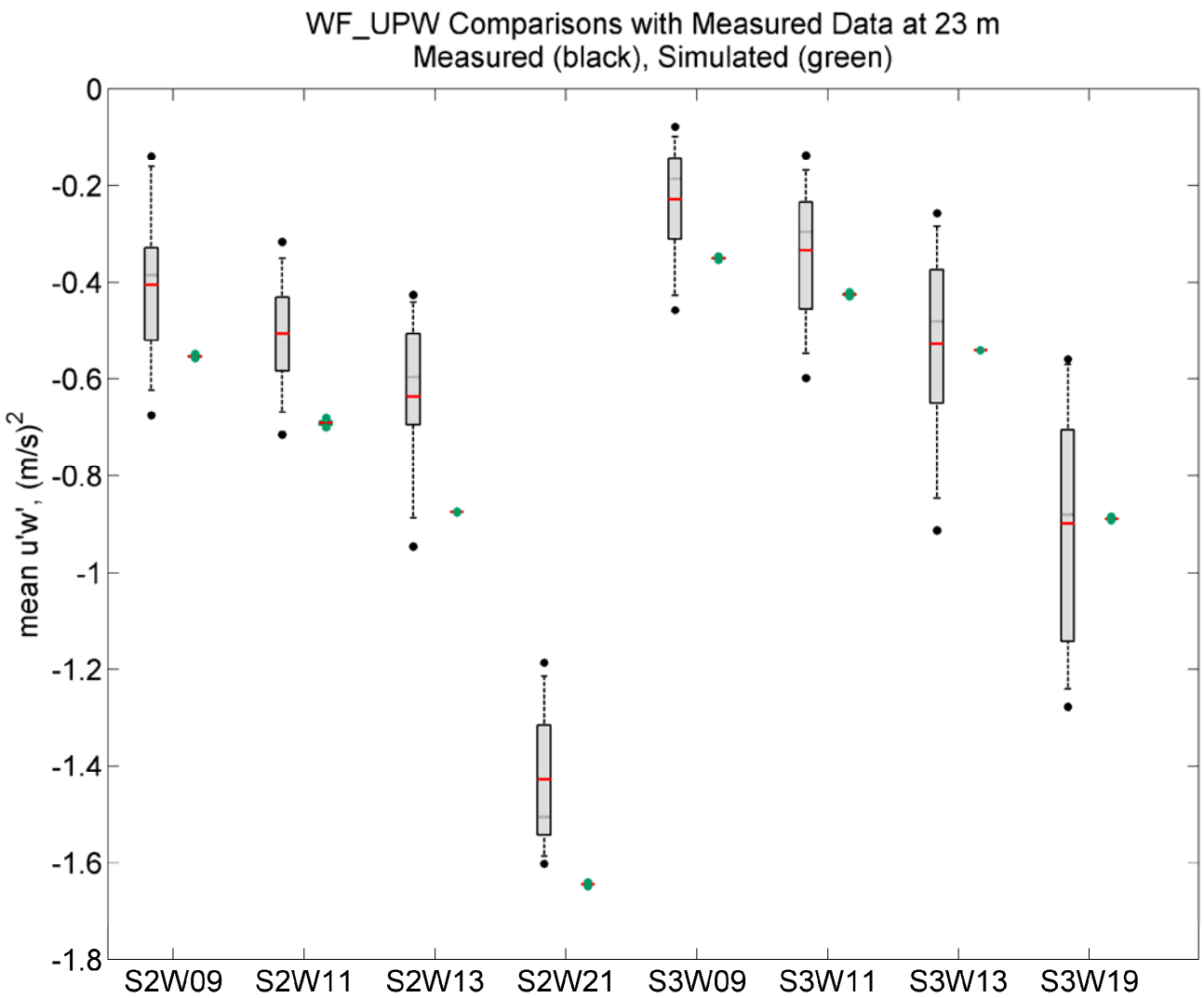
WF_UPW vs. Inflow: Sigma v



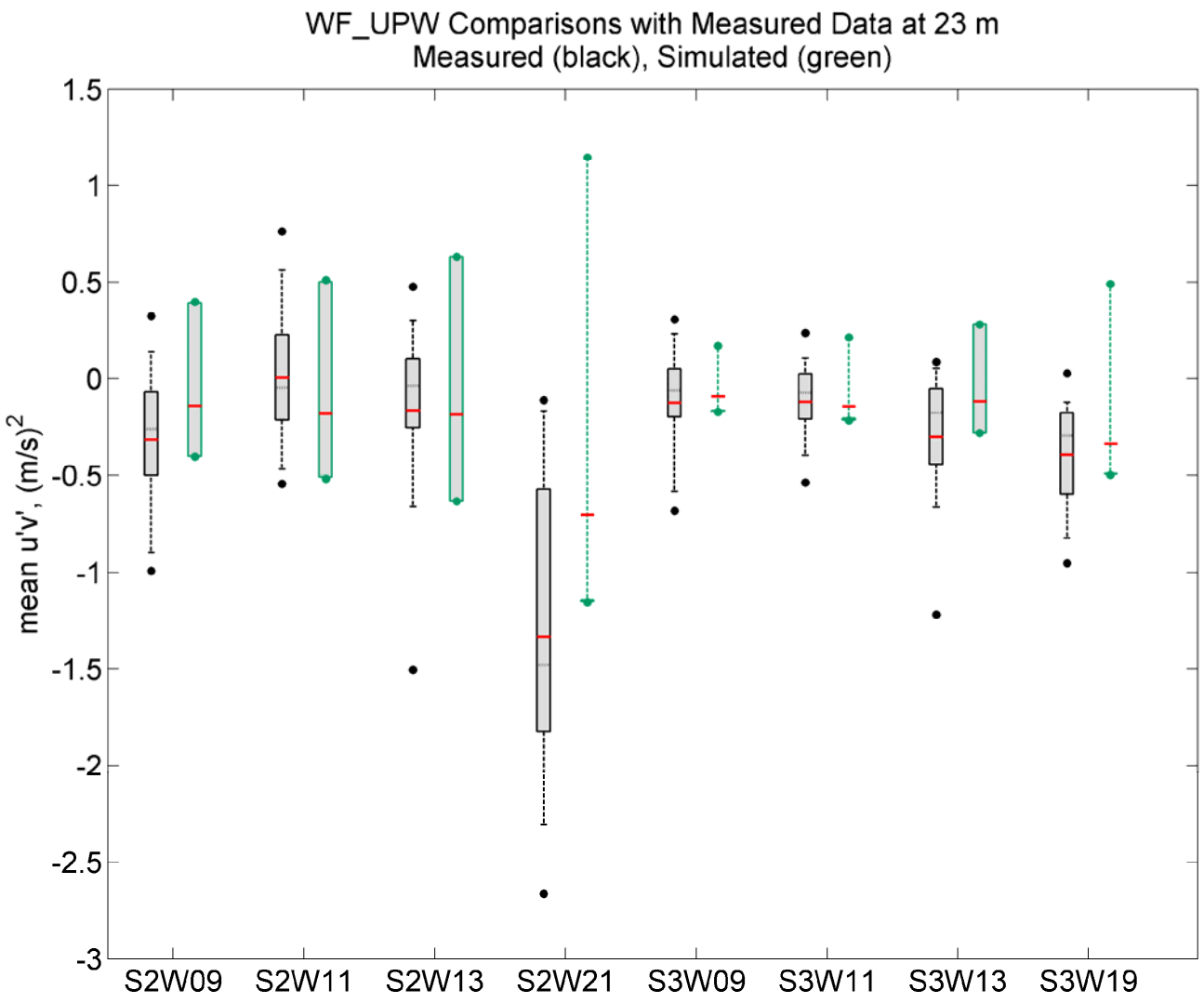
WF_UPW vs. Inflow: Sigma w



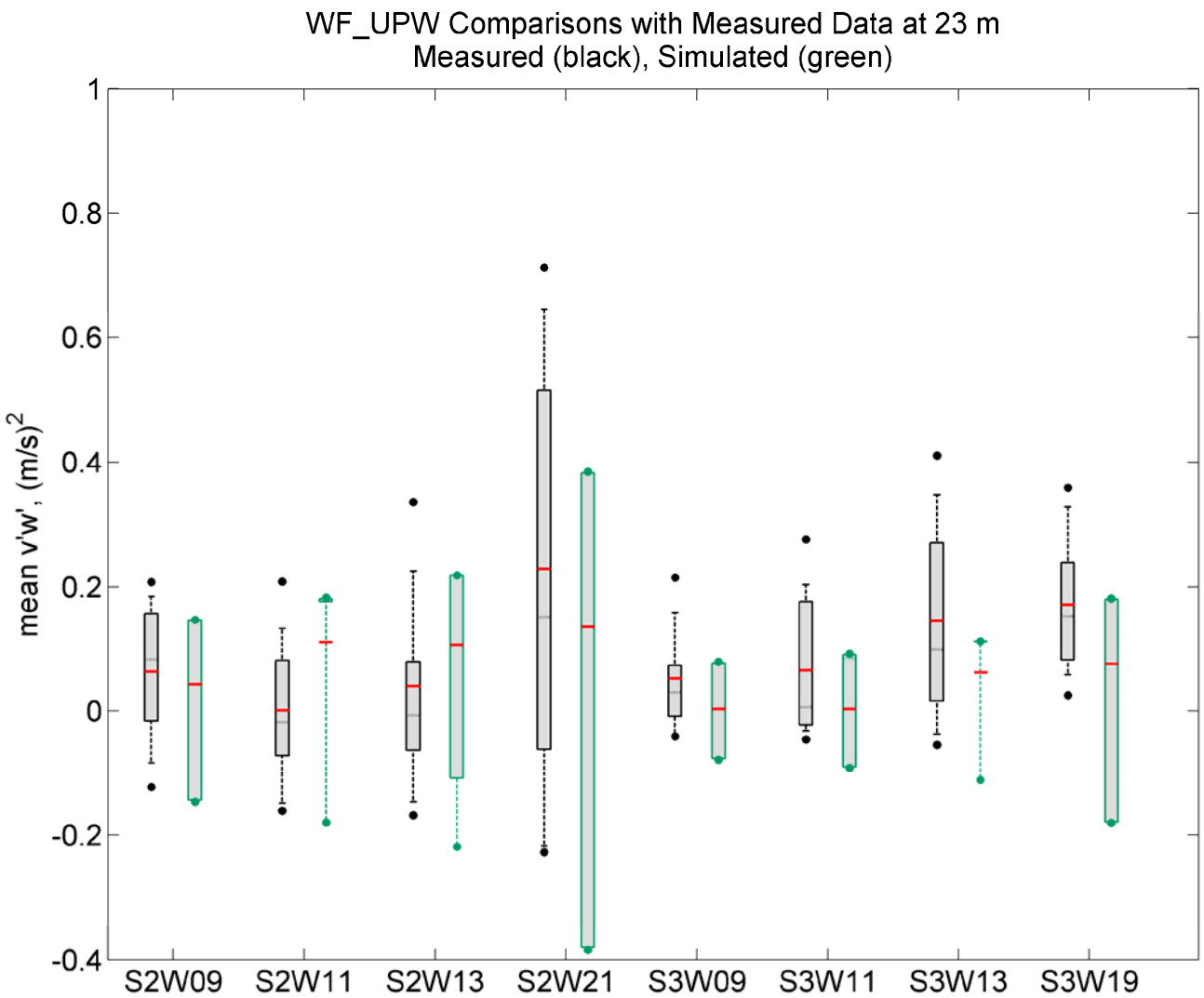
WF_UPW vs. Inflow: Mean u'w'



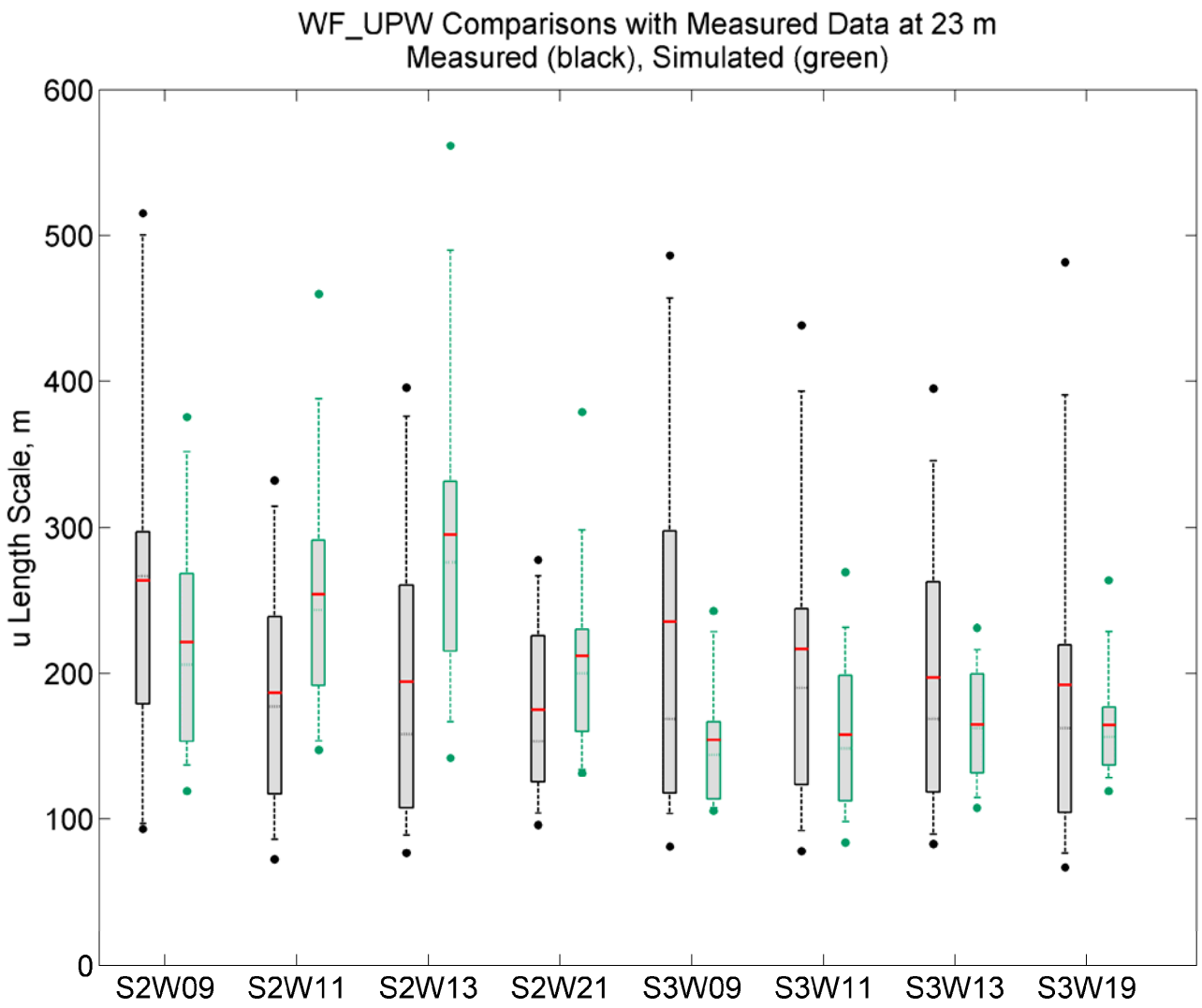
WF_UPW vs. Inflow: Mean u'v'



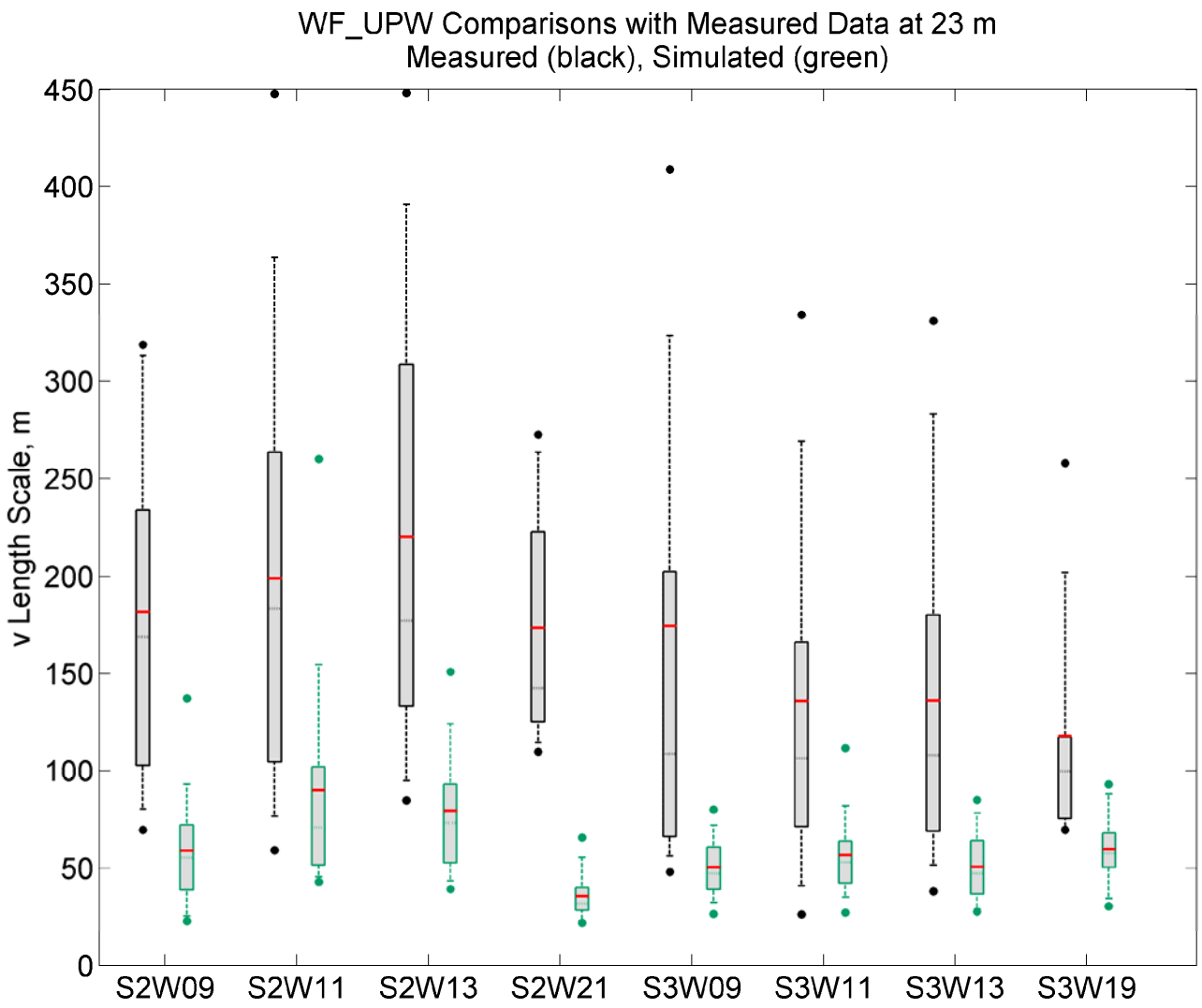
WF_UPW vs. Inflow: Mean v'w'



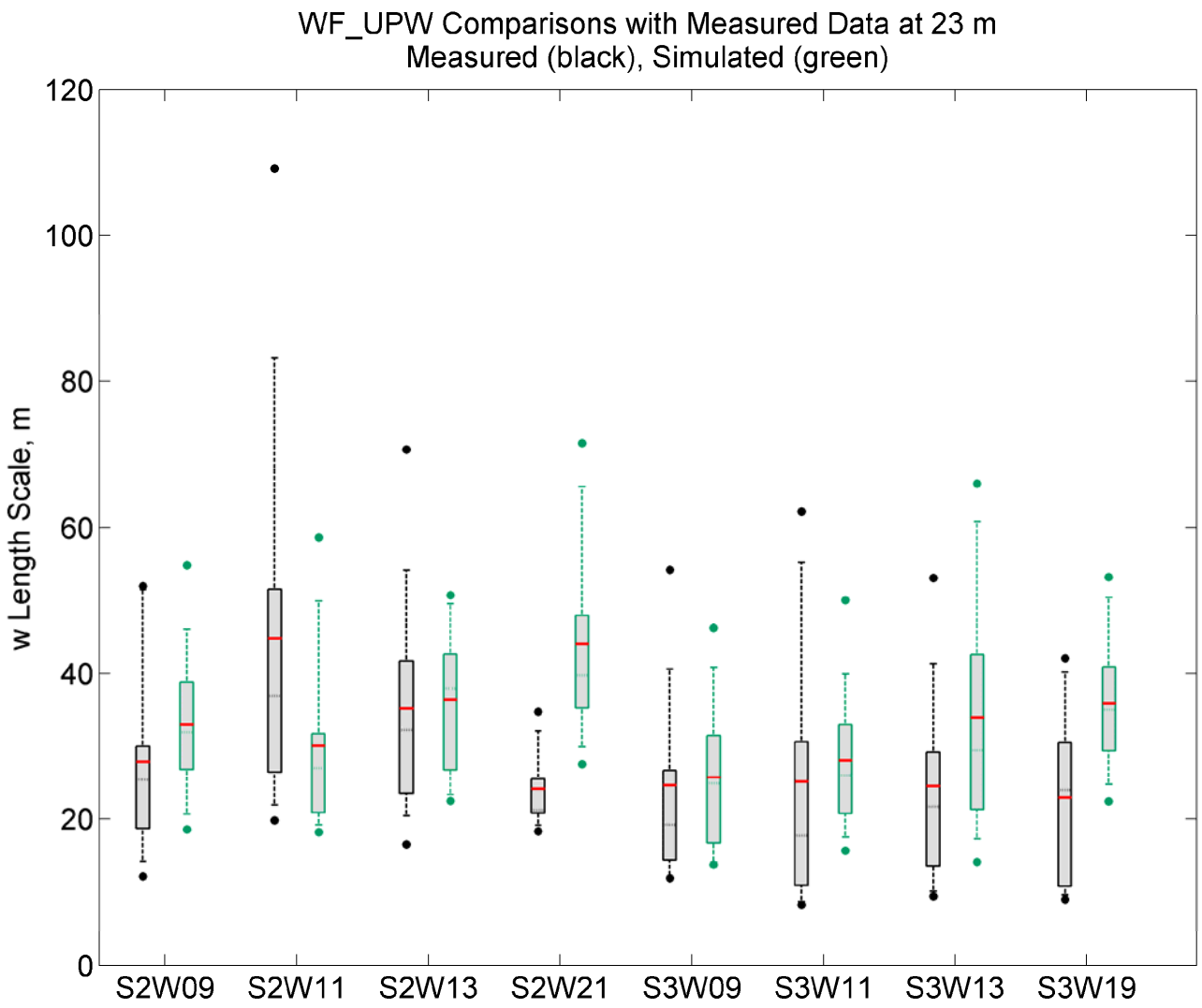
WF_UPW vs. Inflow: L_u



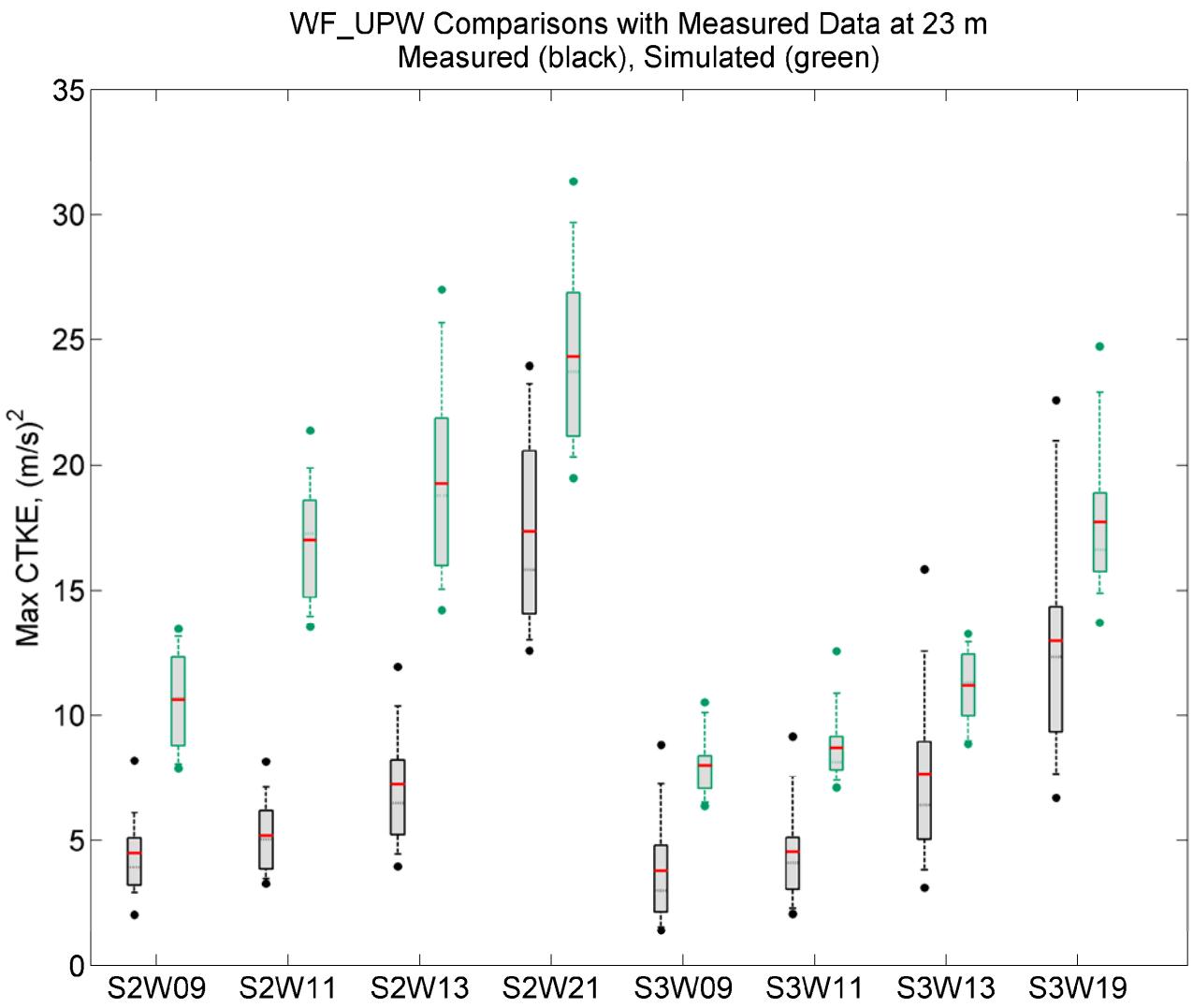
WF_UPW vs. Inflow: L_v



WF_UPW vs. Inflow: L_w



WF_UPW vs. Inflow: Max CTKE

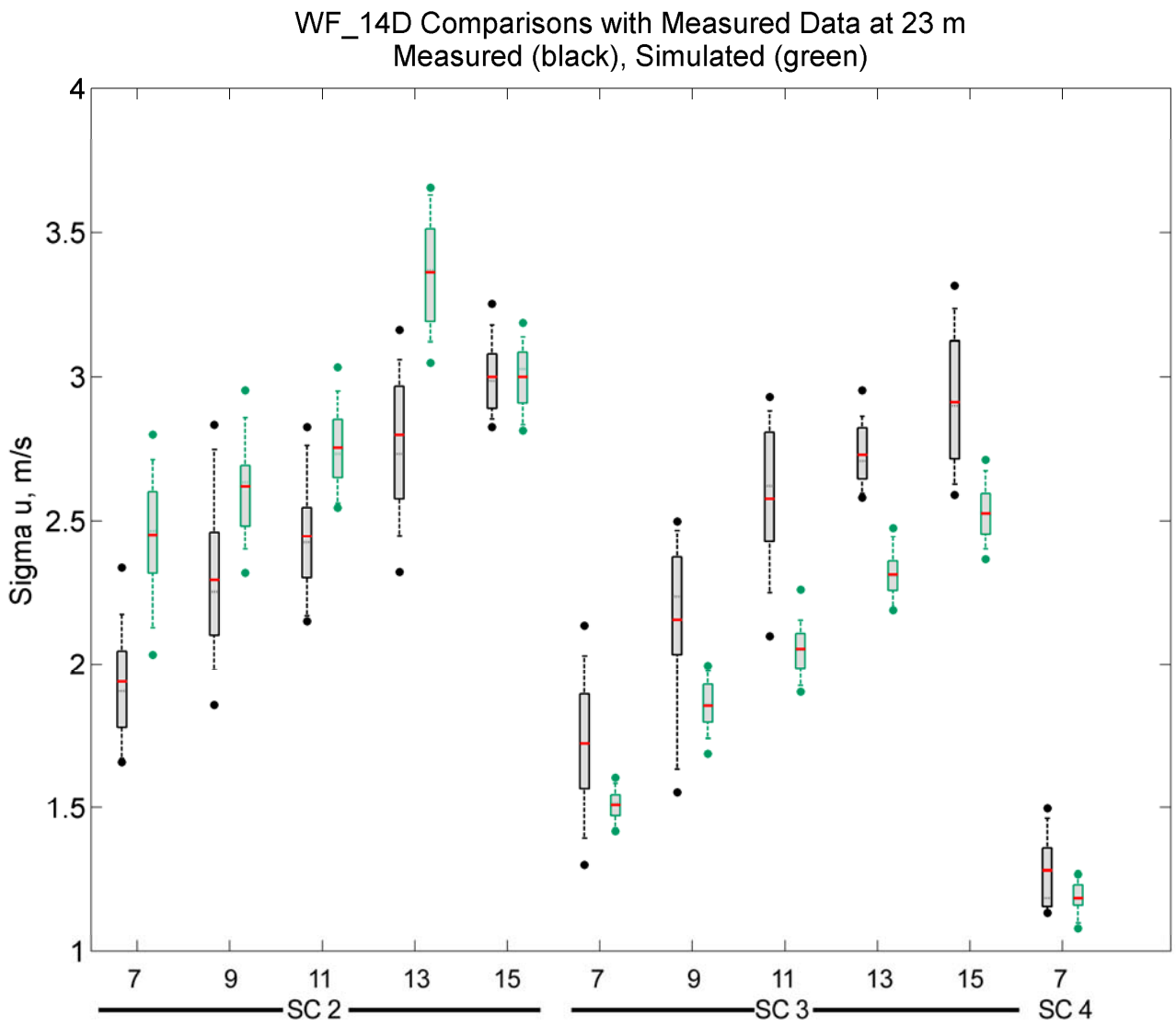


WF_14D Model vs. San Gorgonio Outflow Data

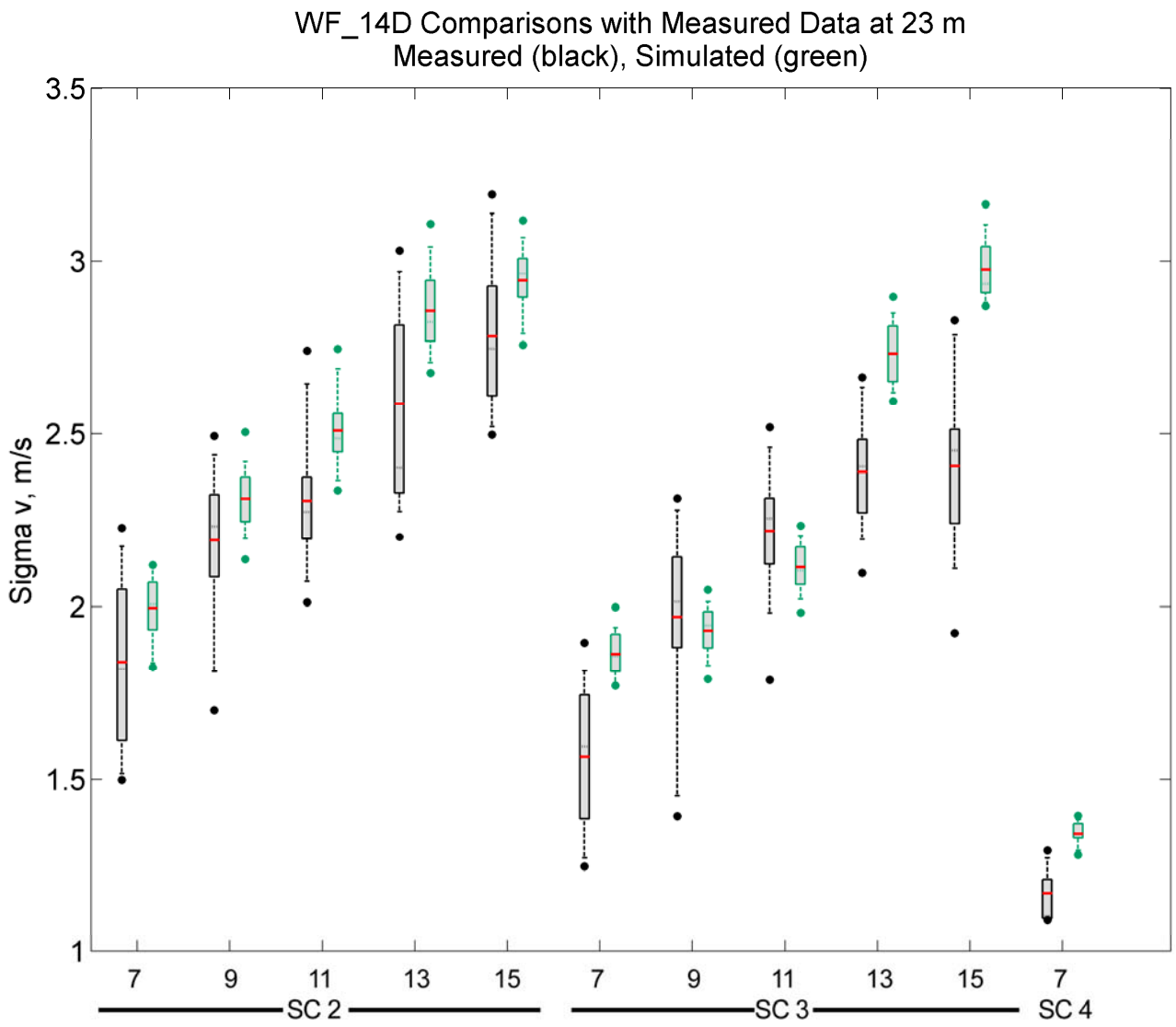
- 11 cases, 31 random seeds each
- 11x11 grid
- 2.3-m grid spacing
- Comparisons at 23-m hub-height

Stability Category \ Wind Speed Bins	3	5	7	9	11	13	15	17	19	21
1	N									
2			L N O	L N I O R	L N I O R	L N I O	O			L N I
3			L N O	L N I O R	L N I O R	L N I O R	O		I	L N
4			L N O	L N R	L N R	L			L	L
5			L	L	L	L		L		

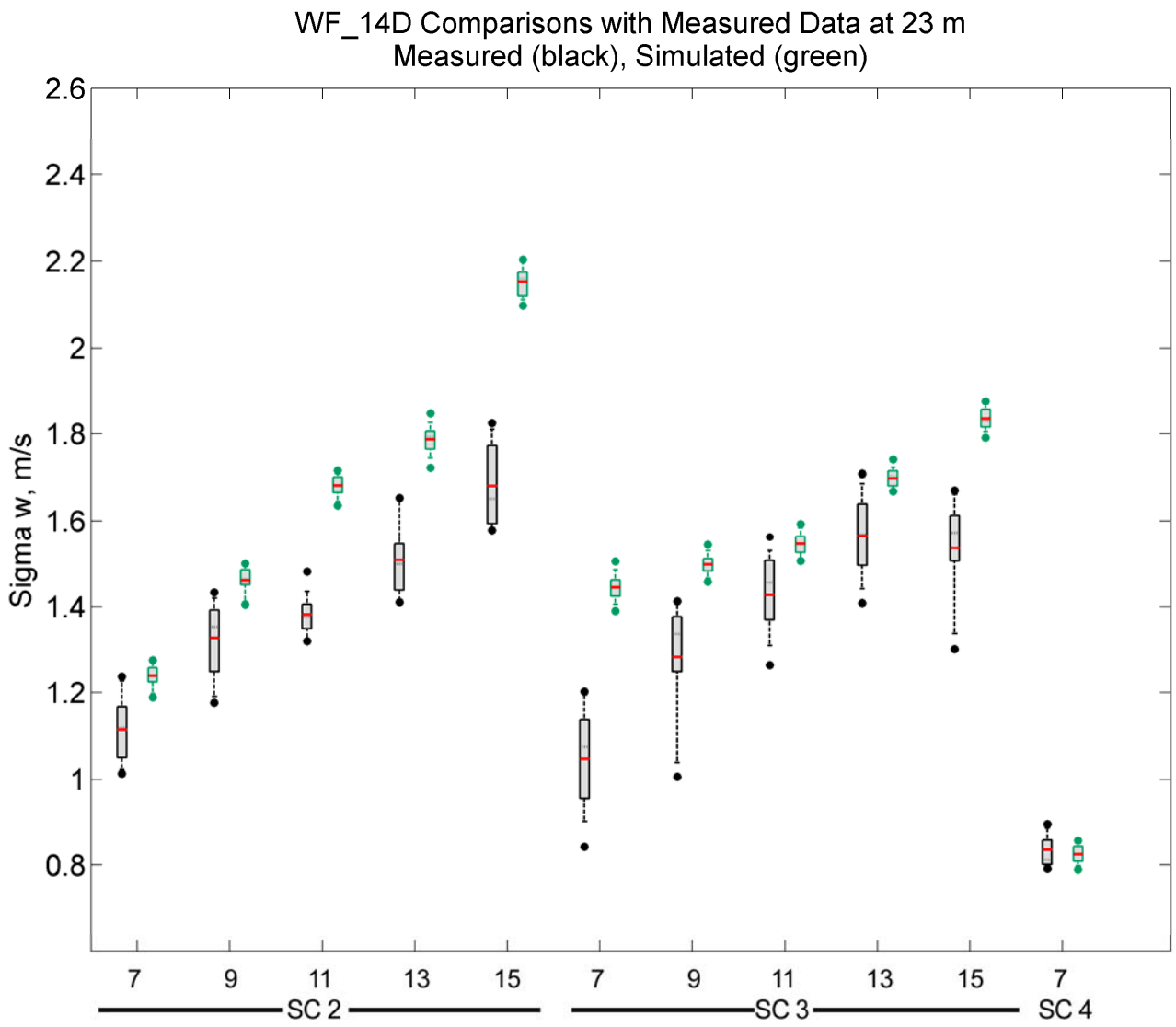
WF_14D vs. Outflow: Sigma u



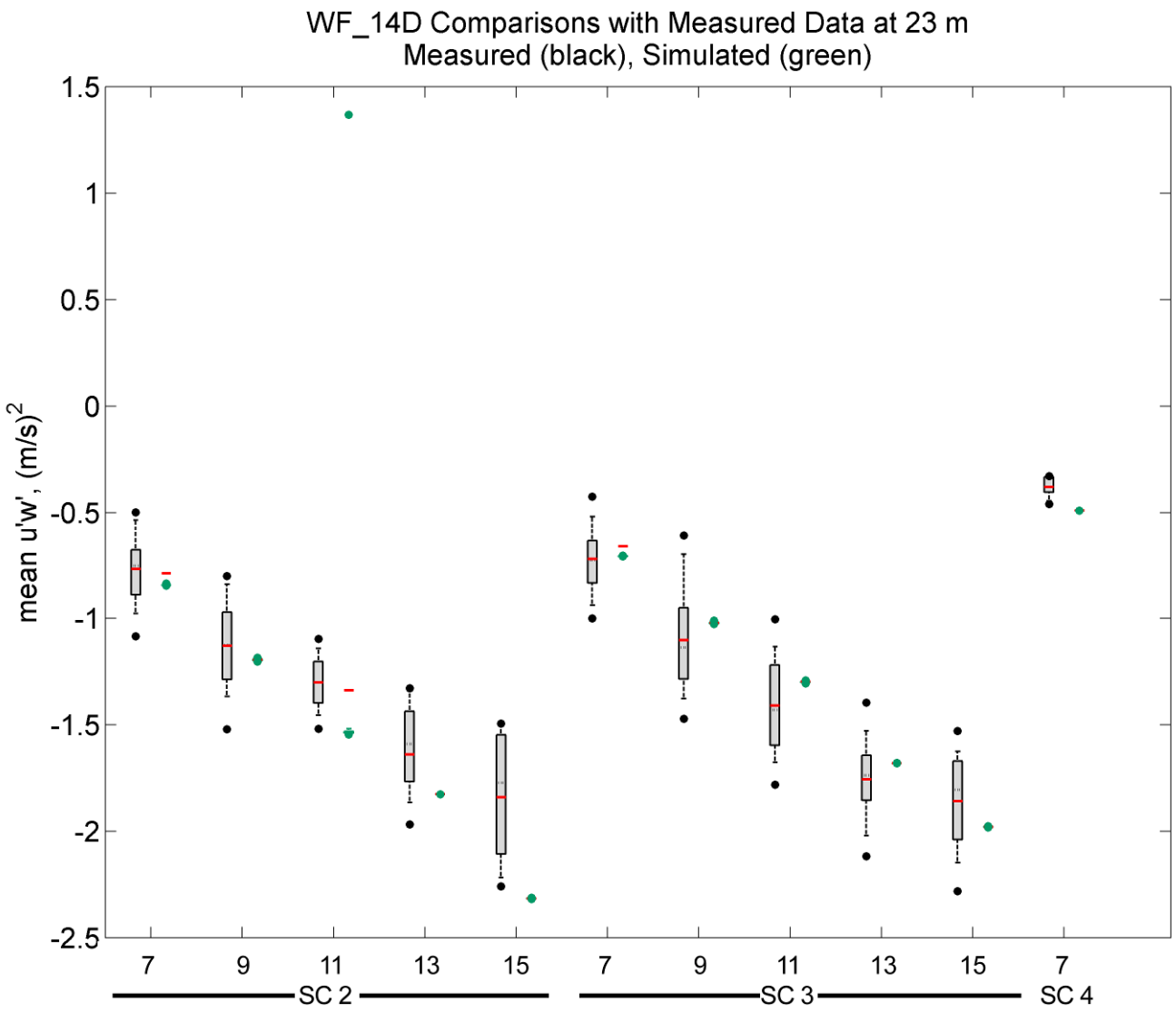
WF_14D vs. Outflow: Sigma v



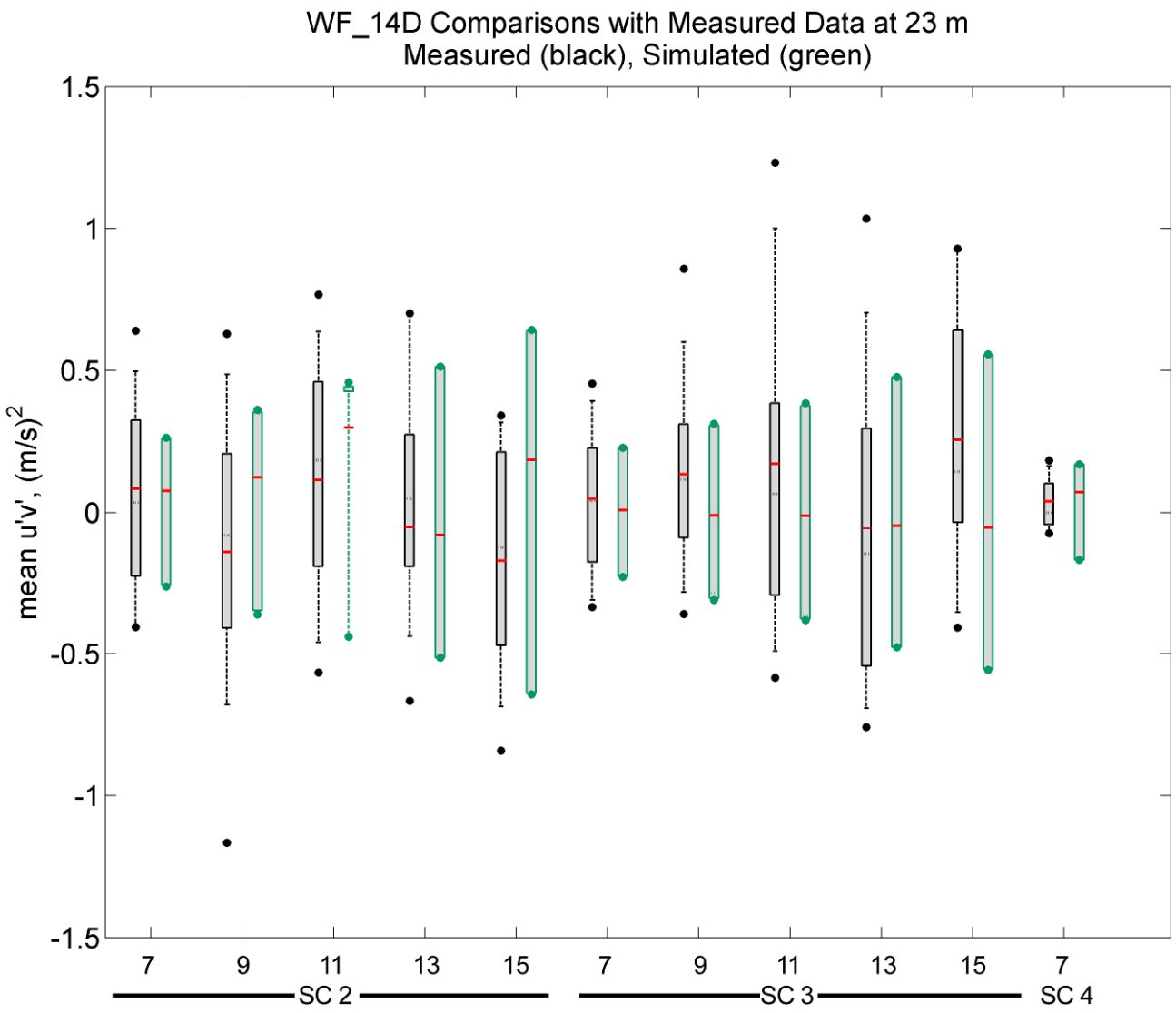
WF_14D vs. Outflow: Sigma w



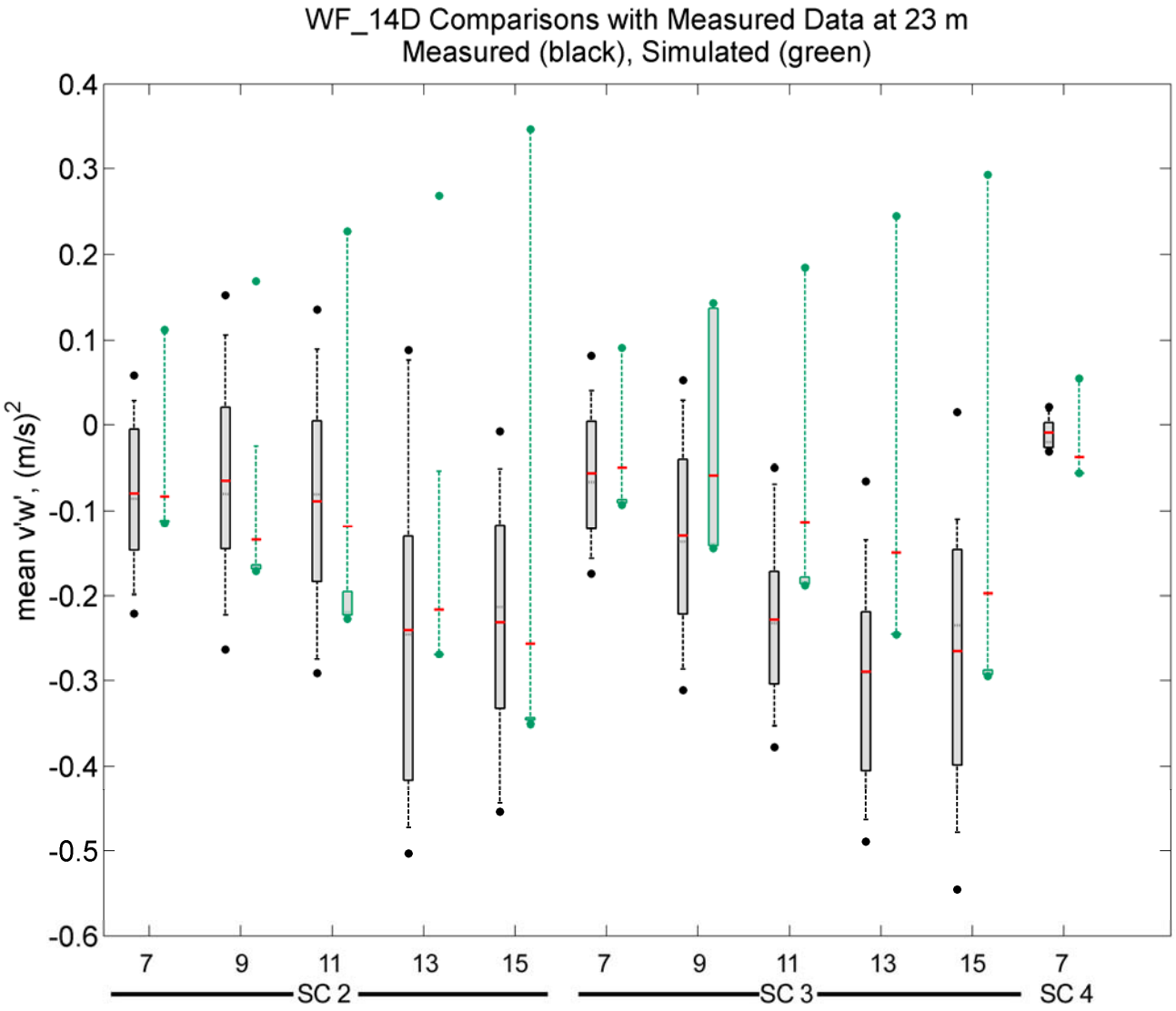
WF_14D vs. Outflow: Mean u'w'



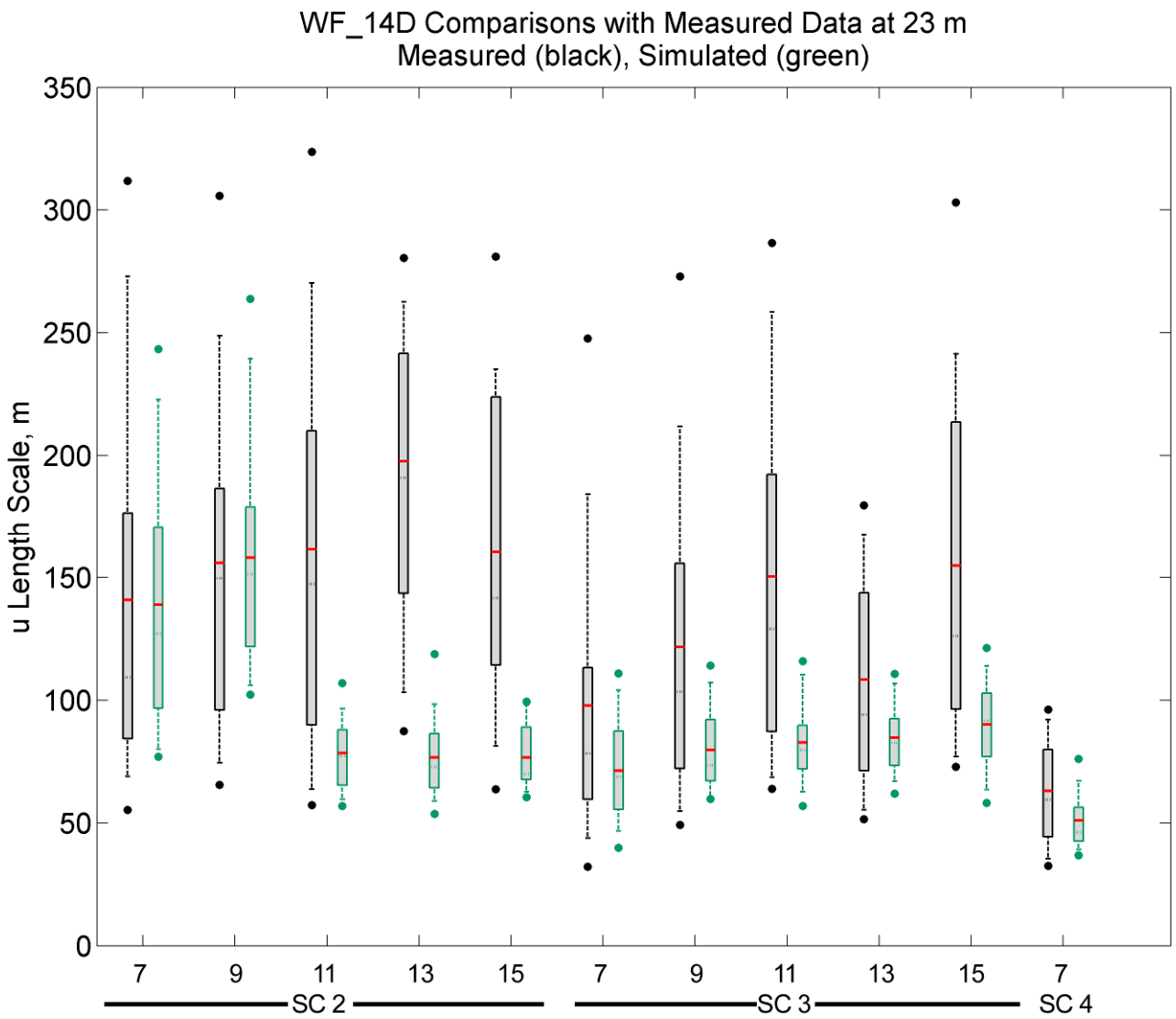
WF_14D vs. Outflow: Mean u'v'



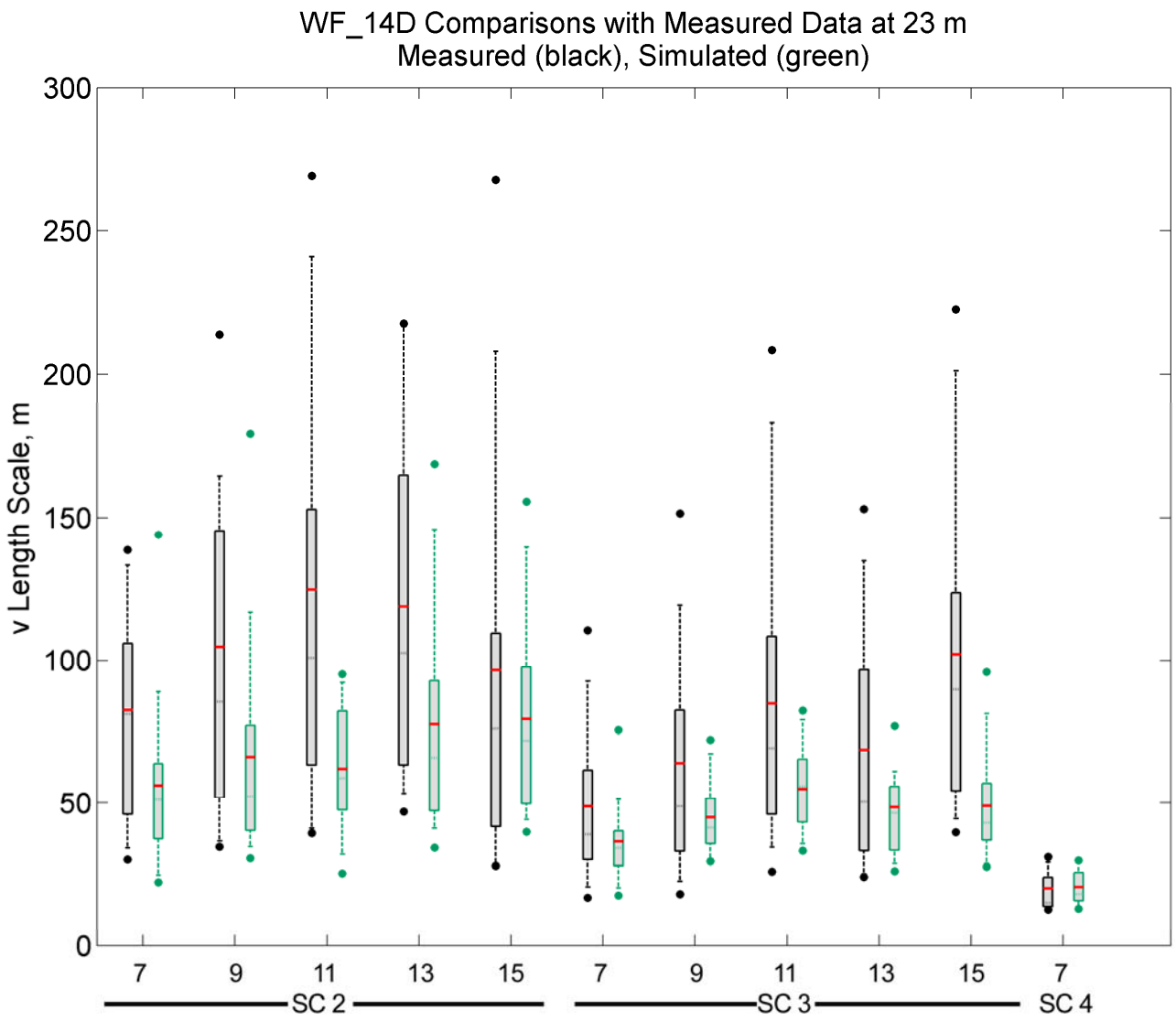
WF_14D vs. Outflow: Mean v'w'



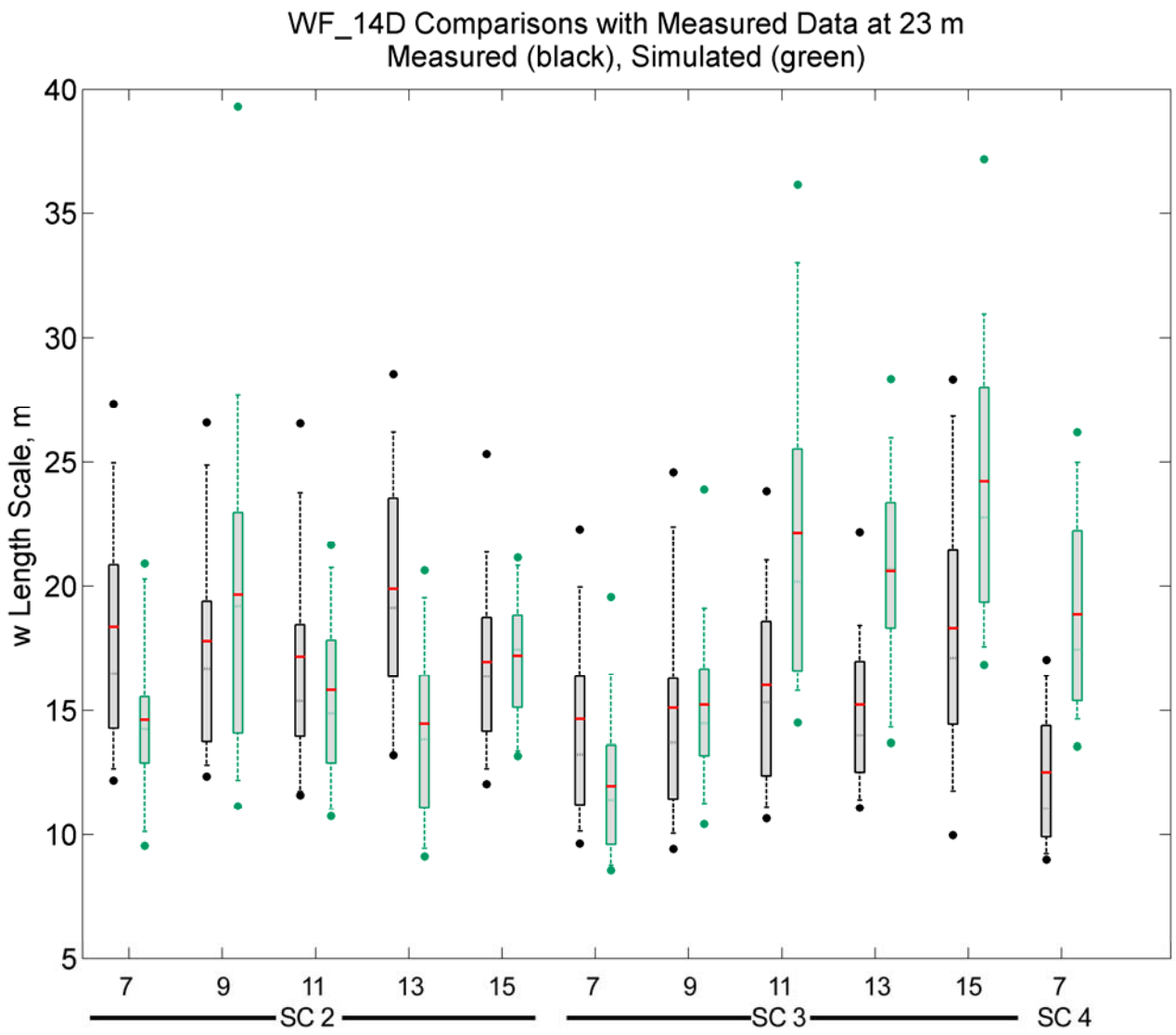
WF_14D vs. Outflow: L_u



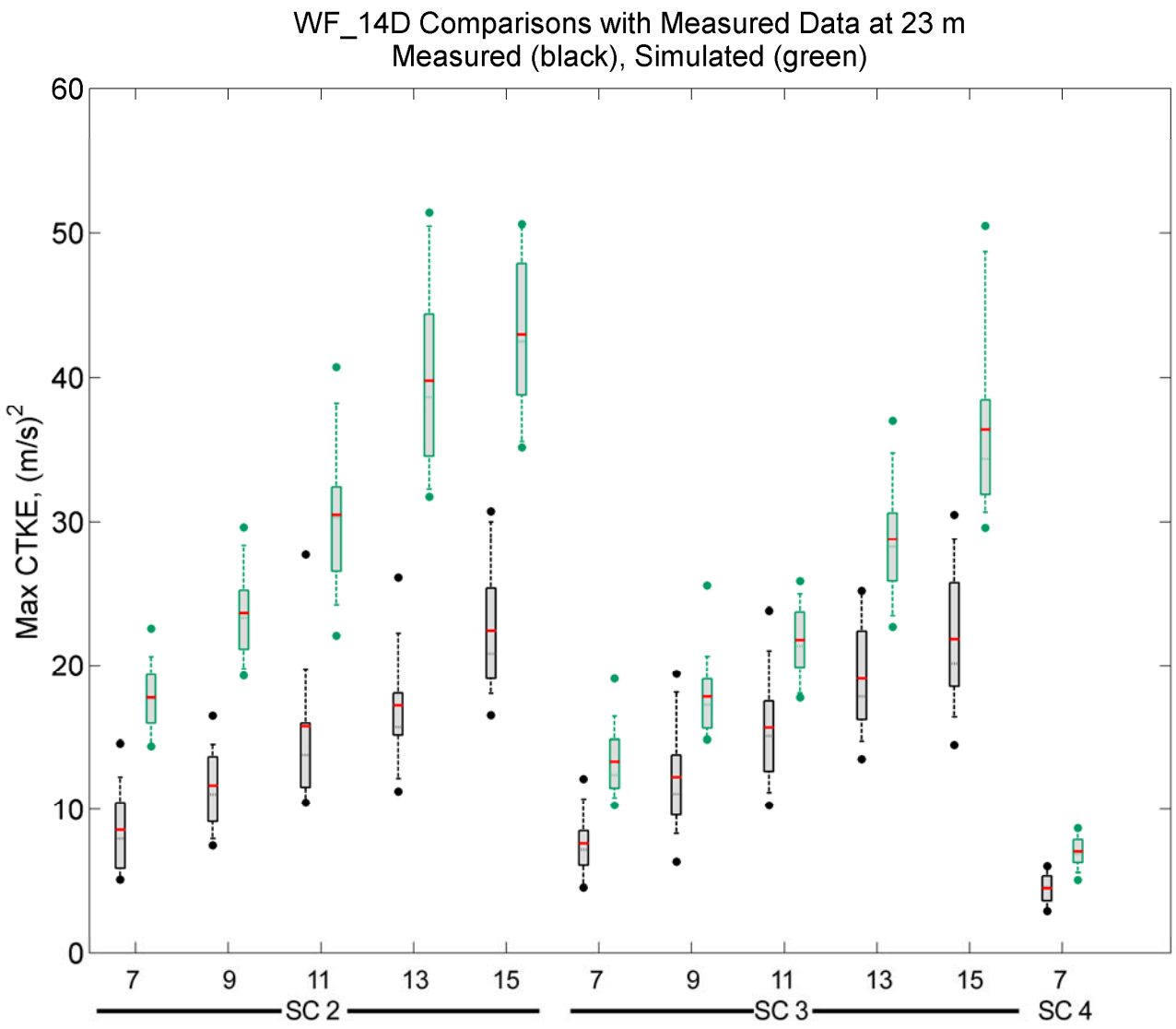
WF_14D vs. Outflow: L_v



WF_14D vs. Outflow: L_w



WF_14D vs. Outflow: Max CTKE

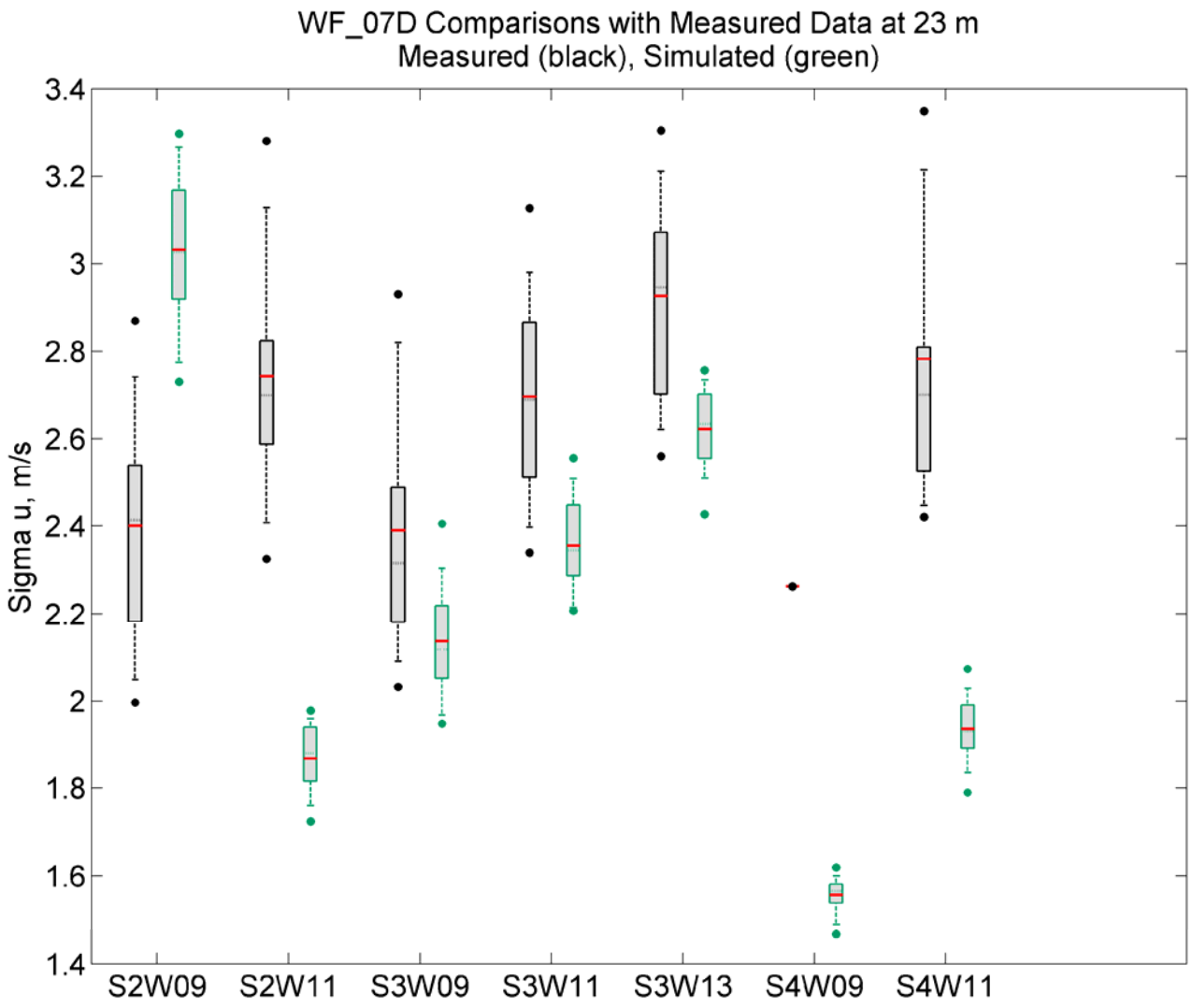


WF_07D Model vs. SeaWest Row 37 Data

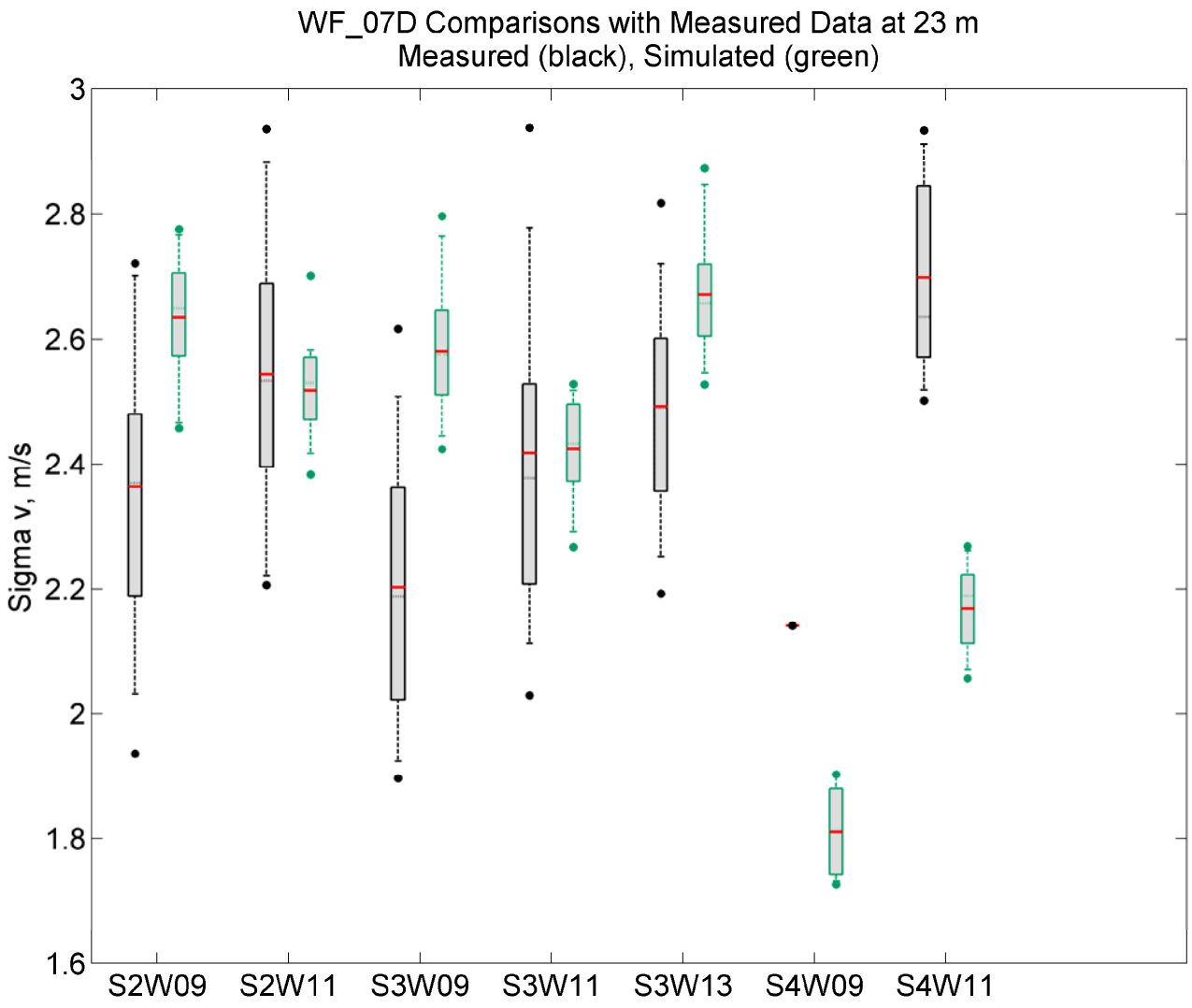
- 7 cases, 31 random seeds each
- 11x11 grid
- 2.3-m grid spacing
- Comparisons at 23-m hub-height

Stability Category	Wind Speed Bins 3	5	7	9	11	13	15	17	19	21
1	N									
2			L N O	L N I O R	L N I O R	L N I O	O			L N I
3			L N O	L N I O R	L N I O R	L N I O R	O		I	L N
4			L N O	L N R	L N R	L			L	L
5			L	L	L	L		L		

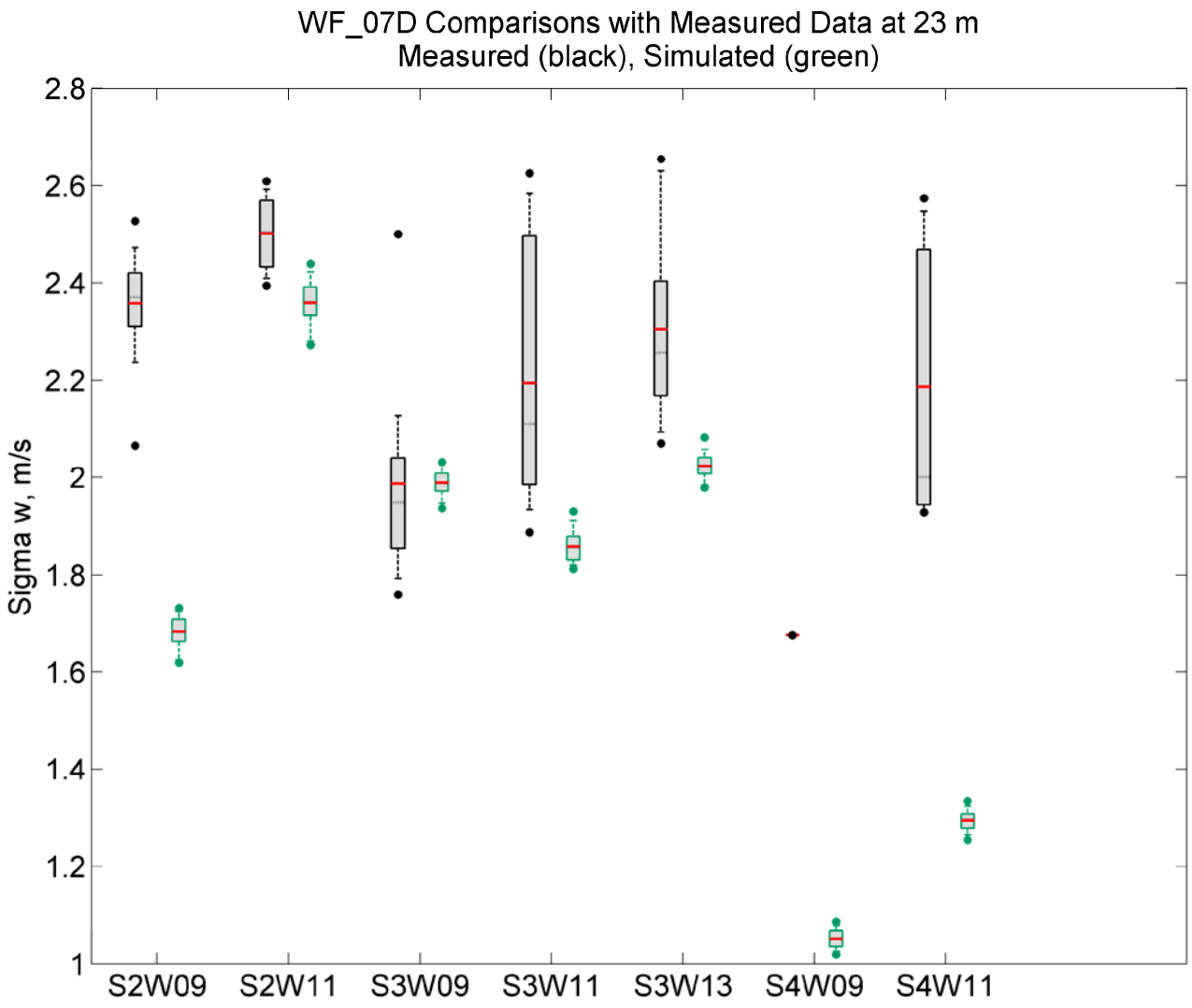
WF_07D vs. Row 37: Sigma u



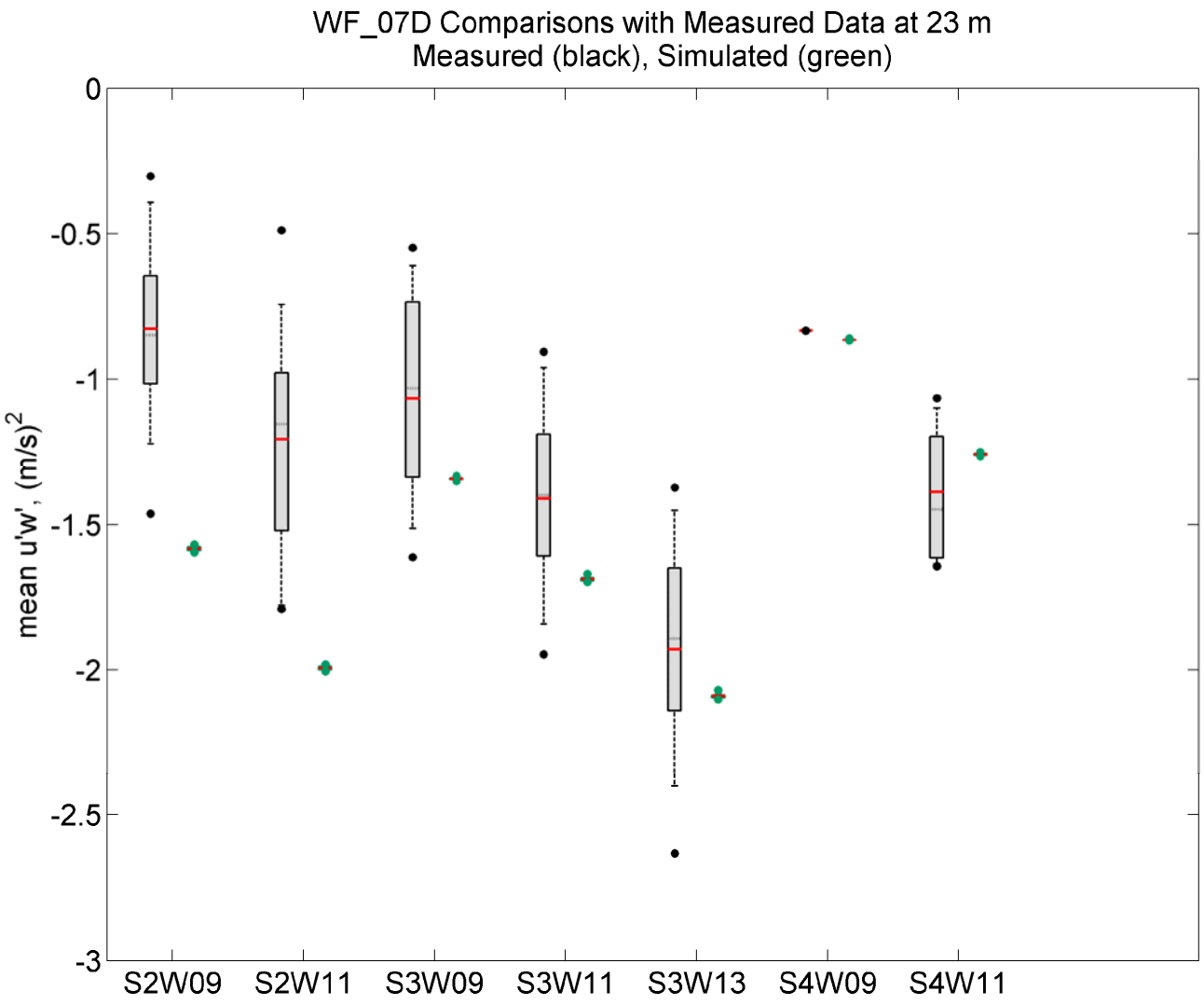
WF_07D vs. Row 37: Sigma v



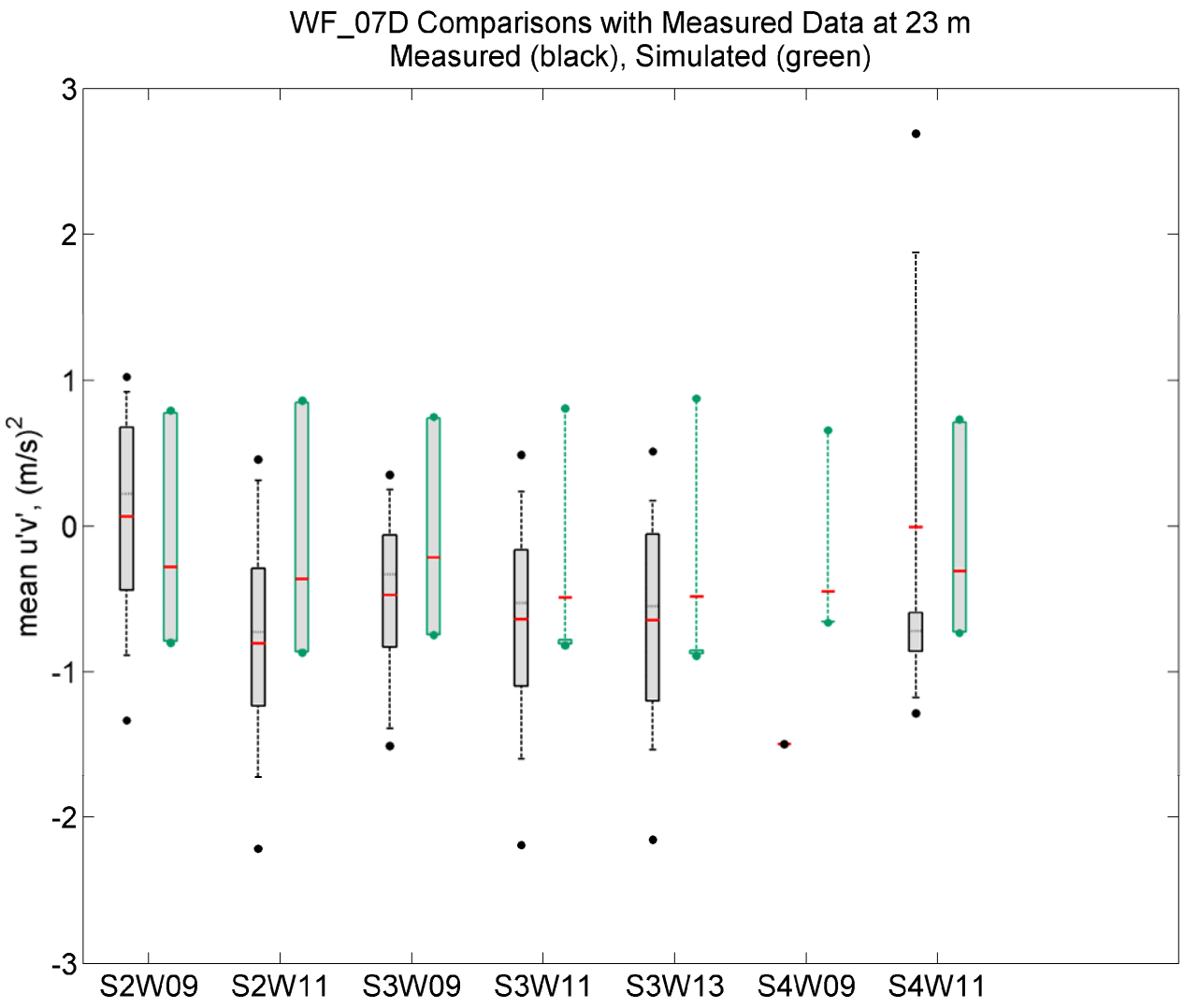
WF_07D vs. Row 37: Sigma w



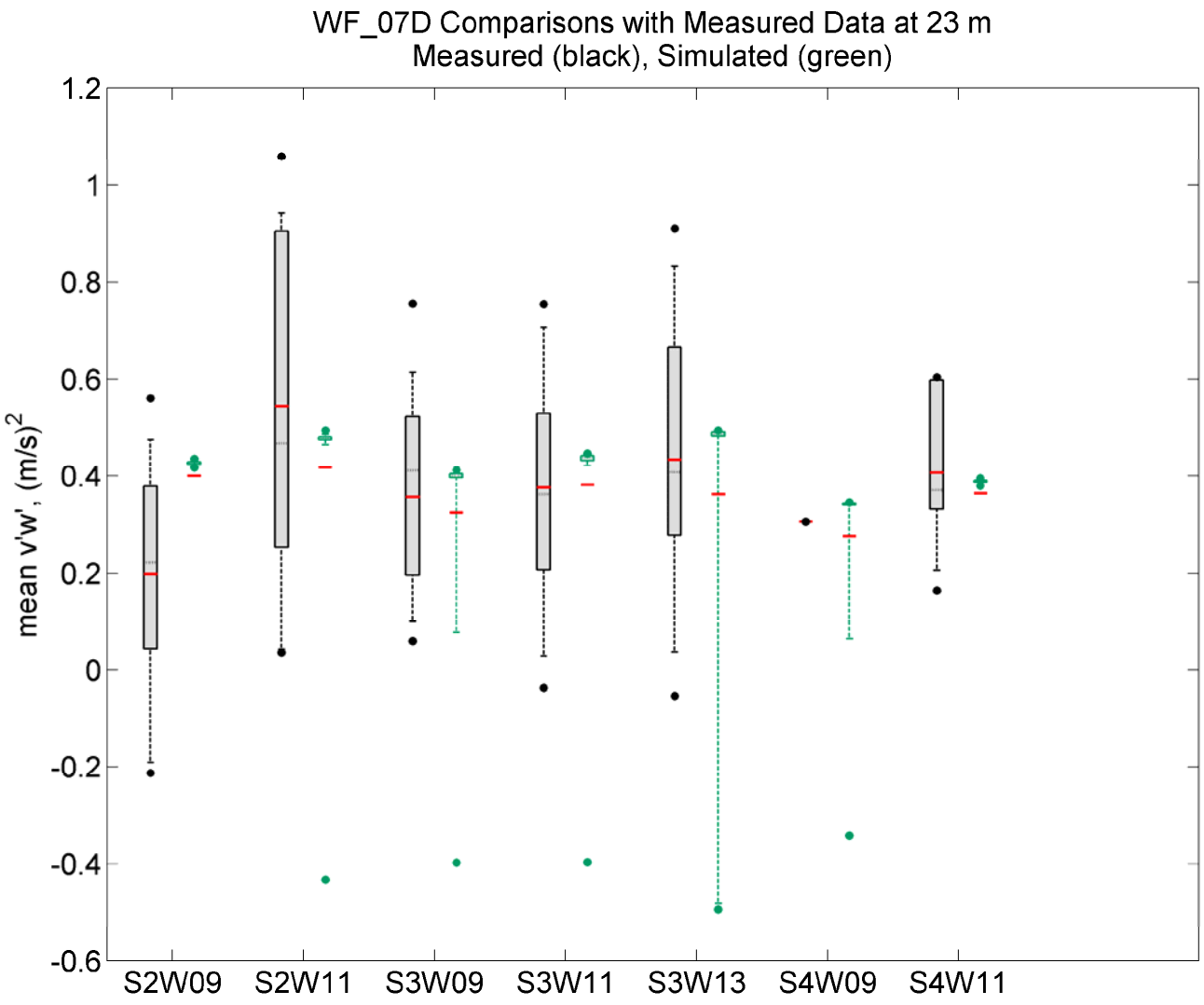
WF_07D vs. Row 37: Mean u'w'



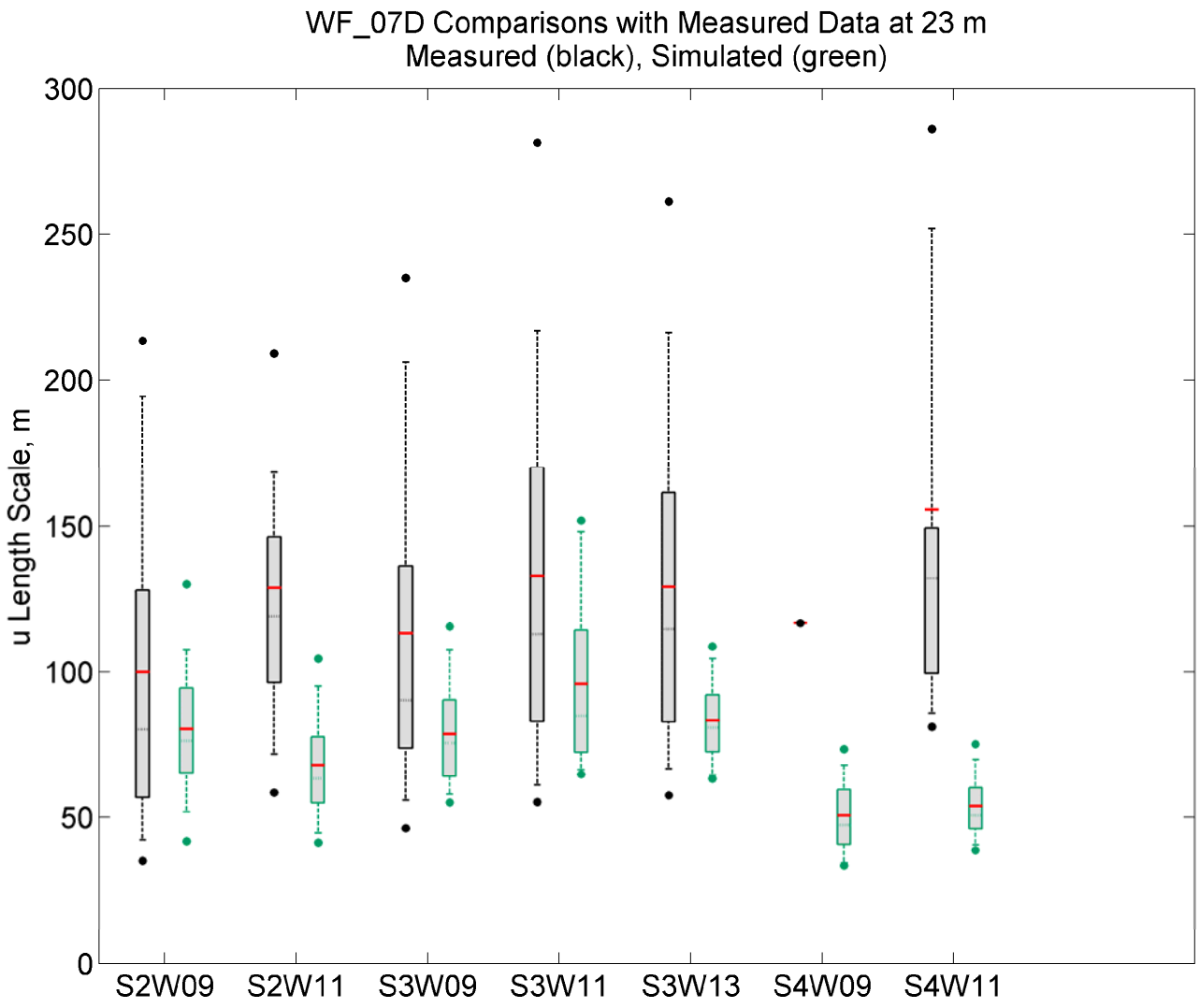
WF_07D vs. Row 37: Mean u'v'



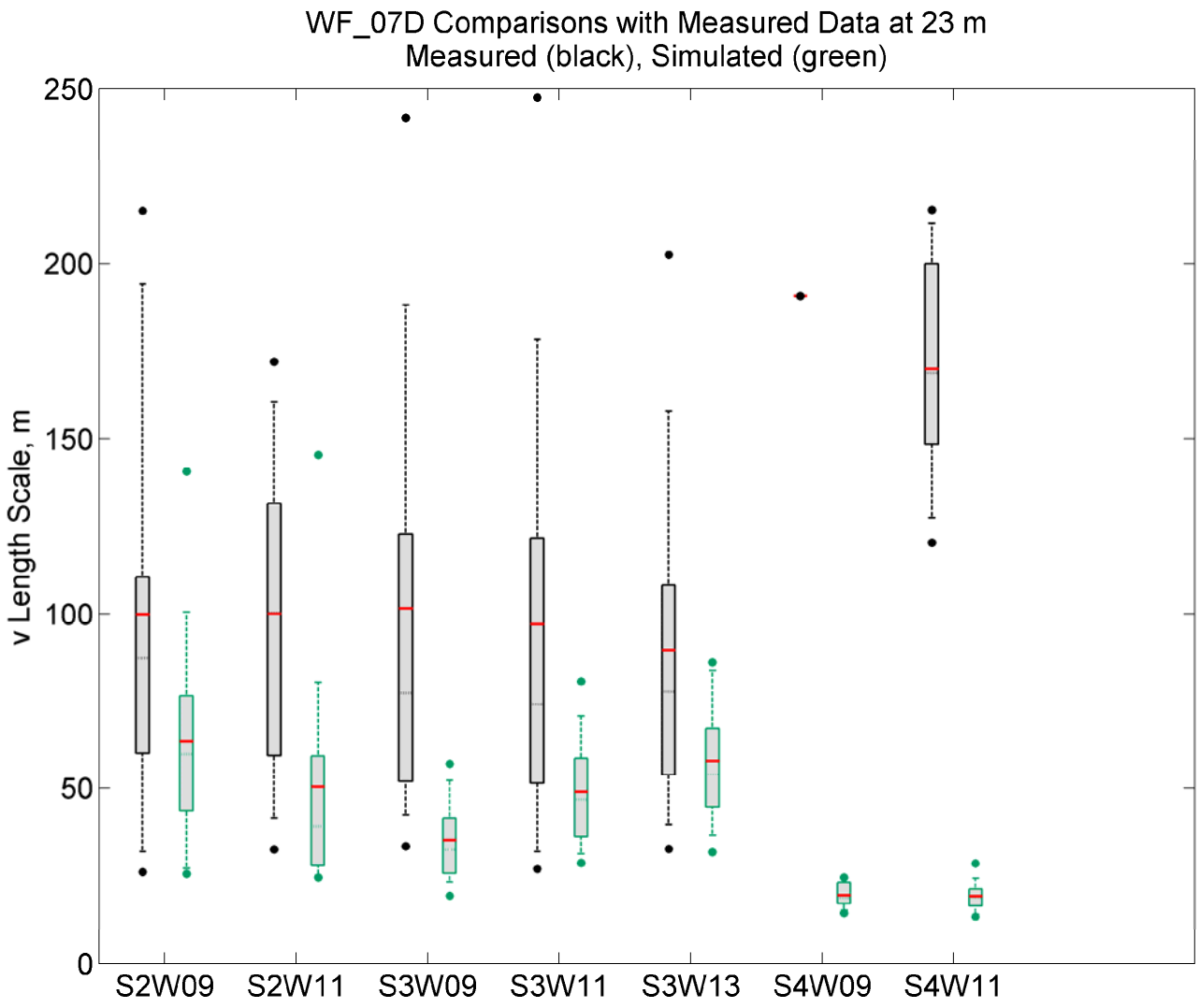
WF_07D vs. Row 37: Mean v'w'



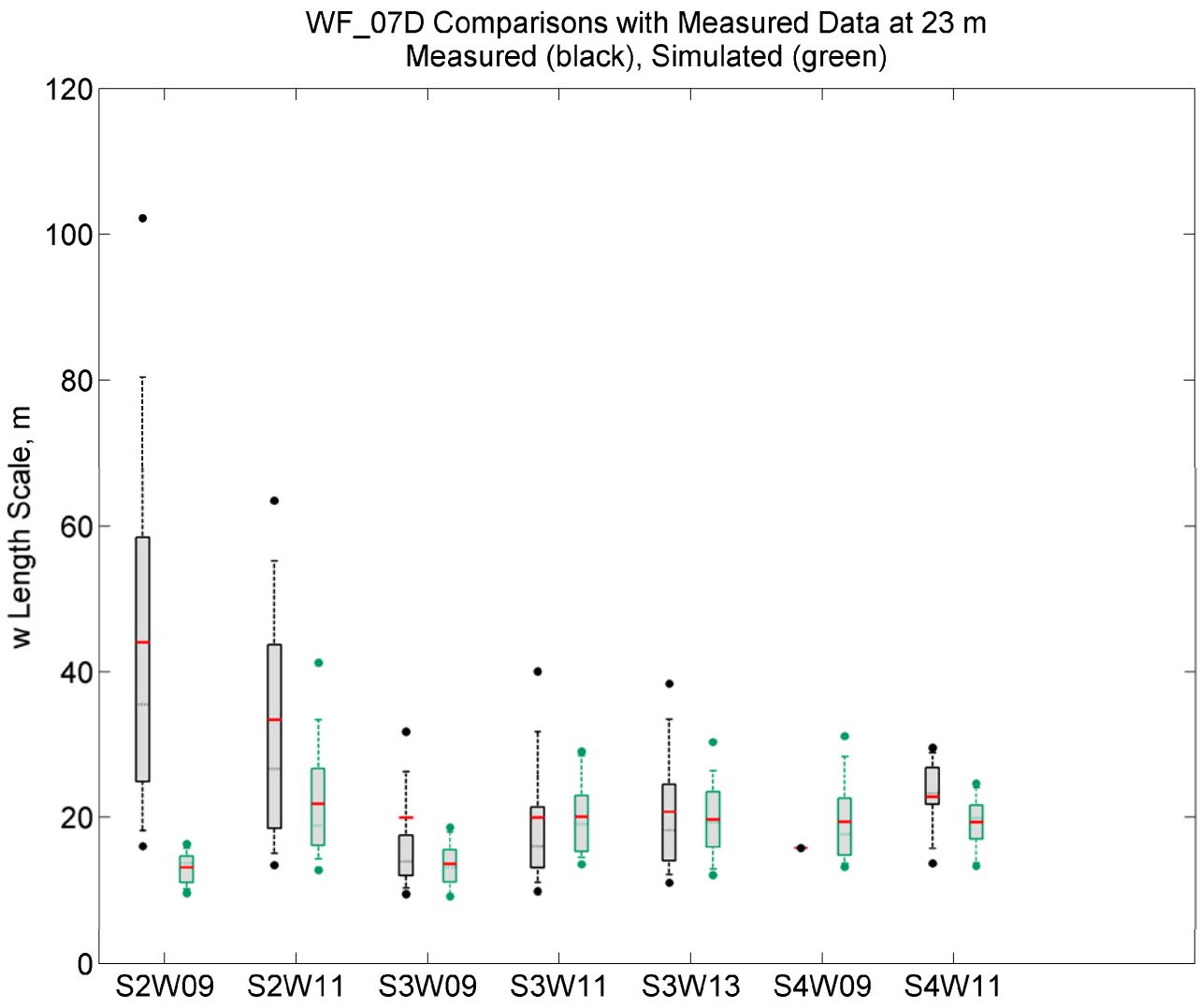
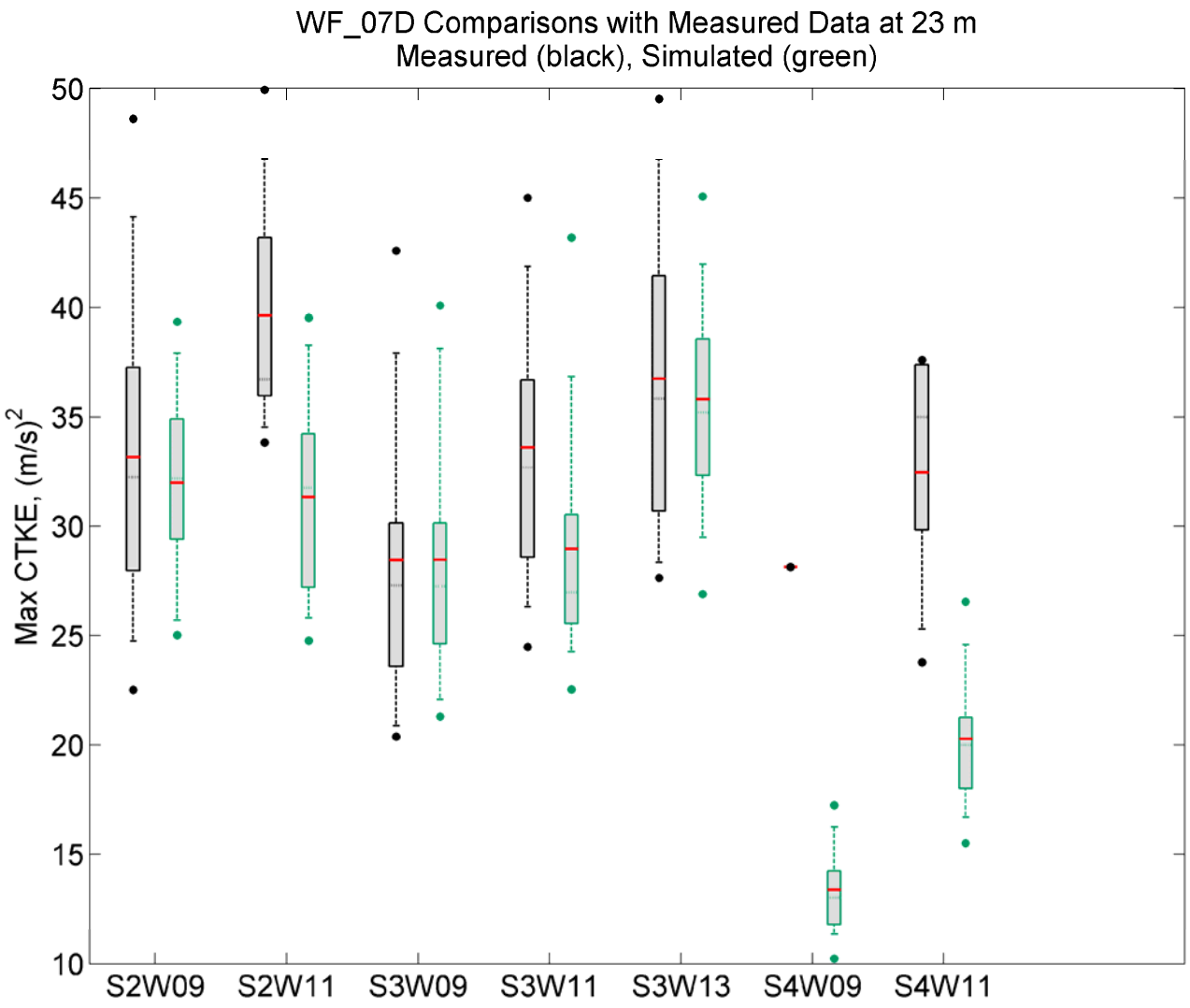
WF_07D vs. Row 37: L_u



WF_07D vs. Row 37: L_v



WF_07D vs. Row 37: L_w



WF_07D vs. Row 37: Max CTKE