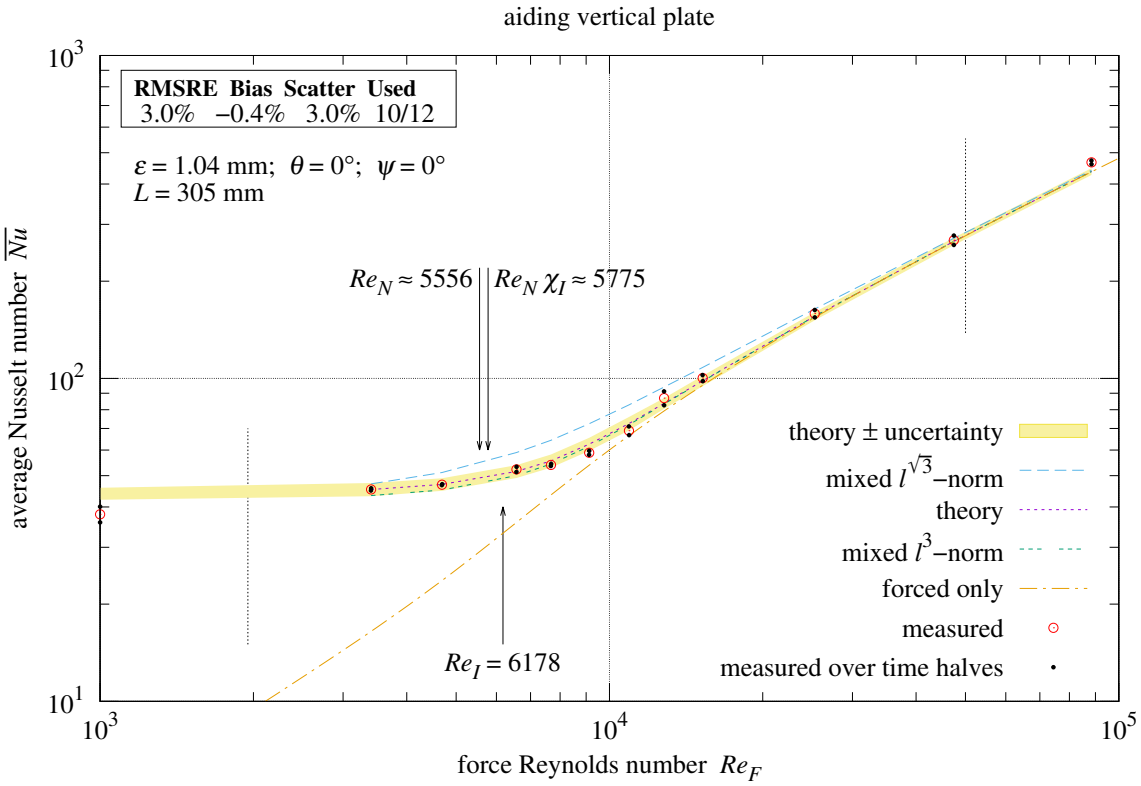
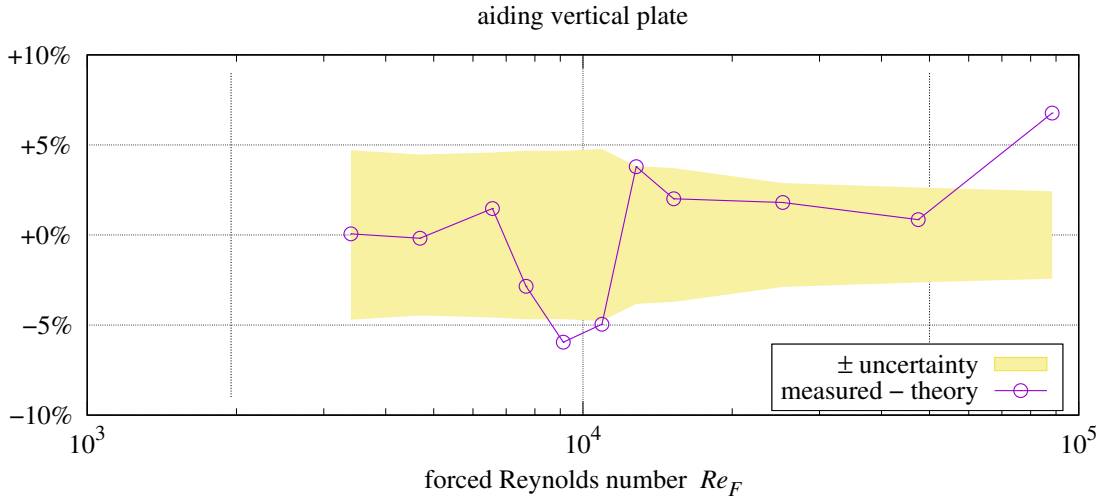
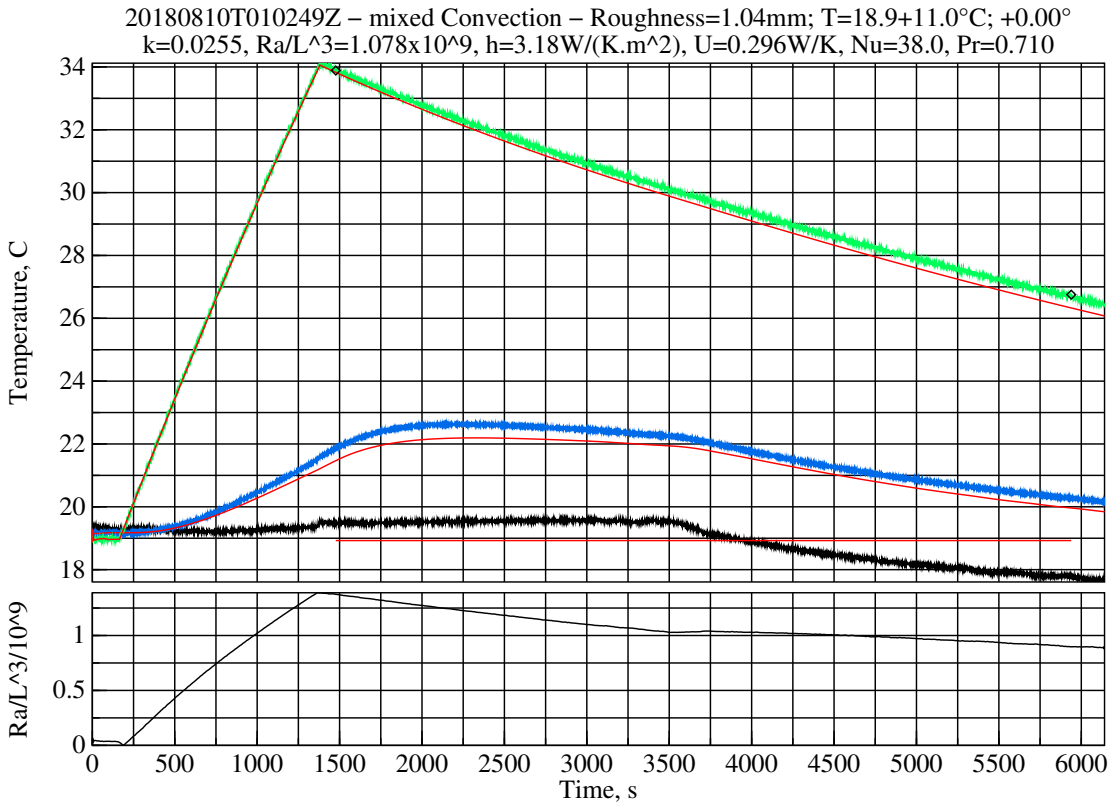
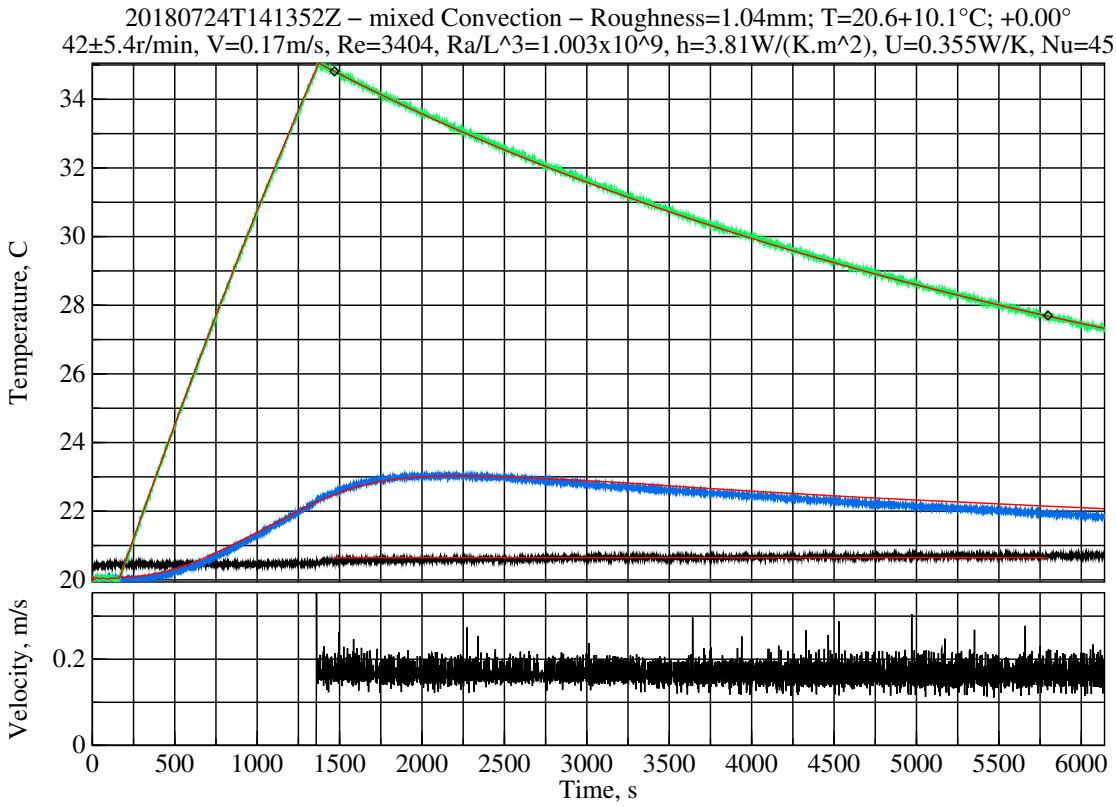

aiding vertical plate
RMSRE Bias Scatter Used
3.0% −0.4% 3.0% 10/12
ε = 1.04 mm; θ = 0°; ψ = 0°
L = 305 mm
Re_N ≈ 5556
Re_N χ_I ≈ 5775
Re_I = 6178
theory ± uncertainty
mixed l^√3–norm
theory
mixed l^3–norm
forced only
measured
measured over time halves
average Nusselt number Nu
force Reynolds number Re_F


aiding vertical plate
± uncertainty
measured – theory
forced Reynolds number Re_F



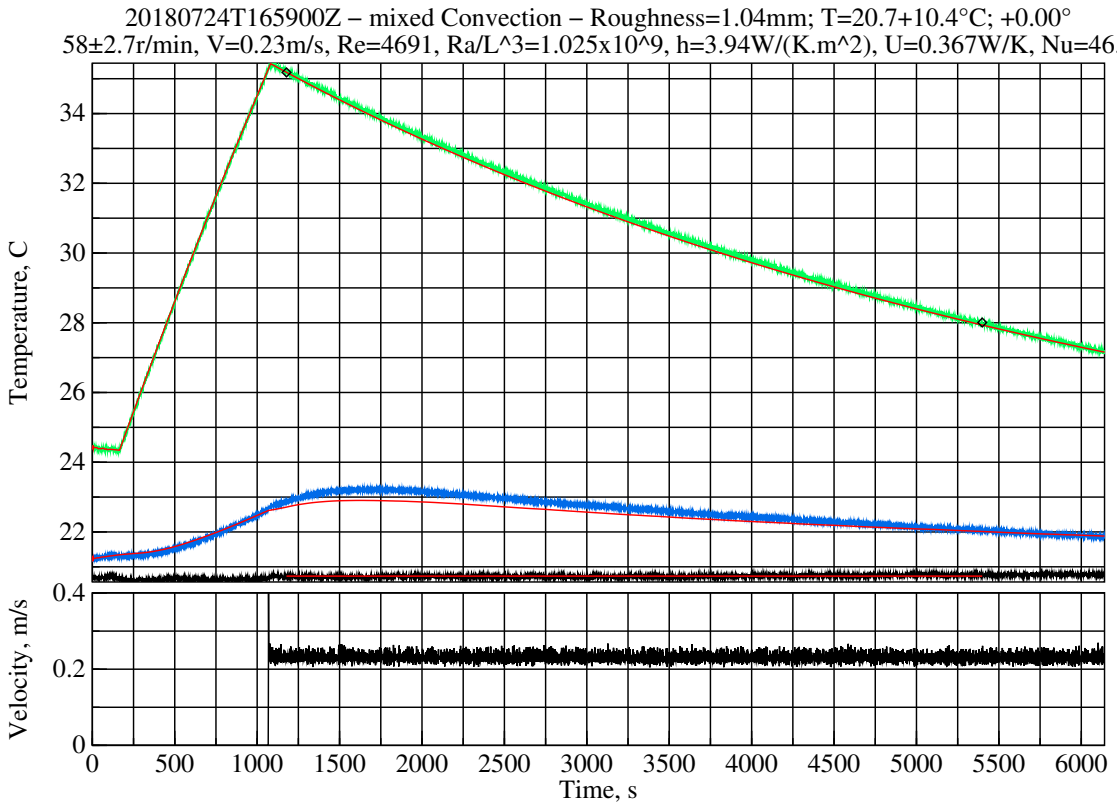
Estimated measurement uncertainties of natural convection at $\theta = 0.0$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	11.0K	+21.0%/K	0.10K	2.10%	LM35C differential
P	100kPa	+0.0007%/Pa	1.5kPa	1.03%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.046%/(J/K)	42J/K	1.96%	plate thermal capacity
C_V	1.000	−13.2%	0.100	1.32%	vertical reuptake
L_c	0.305m	+595%/m	500um	0.30%	characteristic length
D_{PIR}	25.4mm	−511%/m	1.0mm	0.51%	insulation thickness
D_g	1.00mm	−518%/m	500um	0.26%	air gap
L_m	3.57mm	+1093%/m	500um	0.55%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.494\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.55%	PIR thermal conductivity
ϵ_{XPS}	0.515	+35.8%	0.010	0.36%	XPS emissivity
ϵ_{tp}	0.890	+42.9%	0.015	0.64%	tape emissivity
Ω_{tp}	0.540	+29.2%	0.020	0.58%	tape coverage
ϵ_{rs}	0.040	+148%	0.010	1.48%	test-surface emissivity
ϵ_{wt}	0.900	+70.2%	0.025	1.76%	wind-tunnel emissivity
				4.28%	combined bias uncertainty



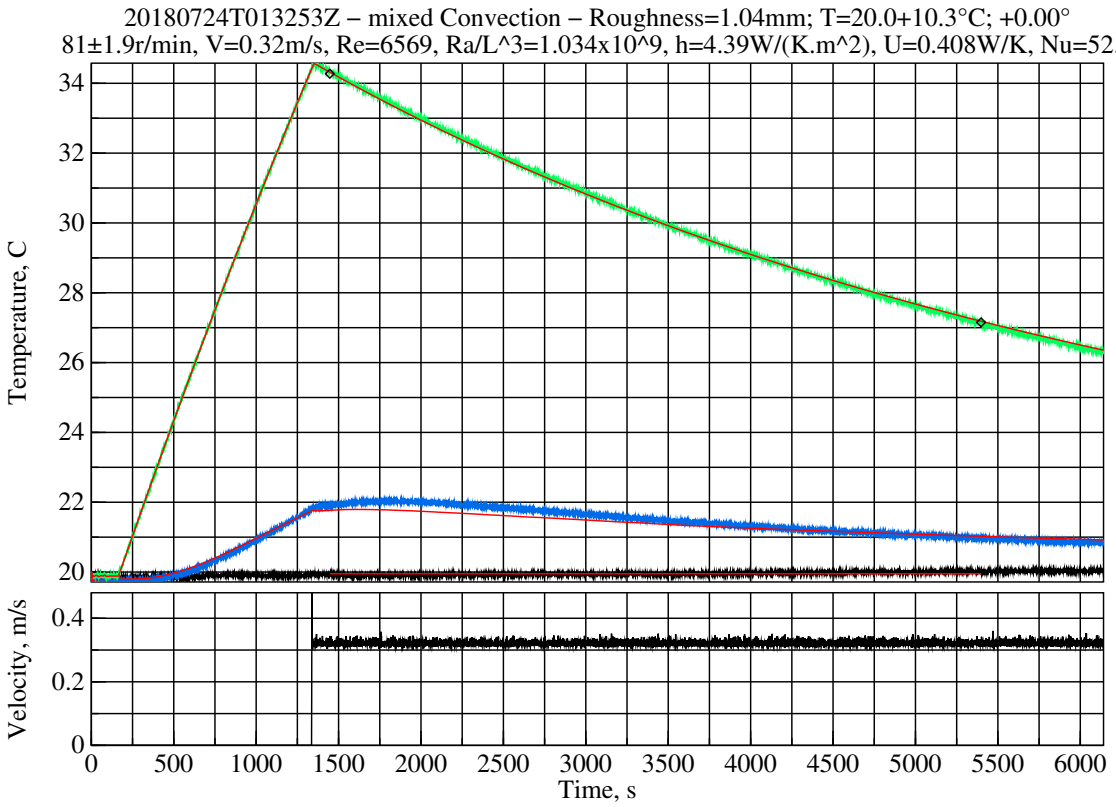
Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 3404$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	10.1K	+22.3%/K	0.10K	2.23%	LM35C differential
P	102kPa	+0.0007%/Pa	1.5kPa	1.06%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.046%/(J/K)	42J/K	1.94%	plate thermal capacity
C_V	1.000	−12.5%	0.100	1.25%	vertical reuptake
L_c	0.305m	+549%/m	500um	0.27%	characteristic length
D_{PIR}	25.4mm	−496%/m	1.0mm	0.50%	insulation thickness
D_g	1.00mm	−503%/m	500um	0.25%	air gap
L_m	3.57mm	+1191%/m	500um	0.60%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.492\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.55%	PIR thermal conductivity
ϵ_{XPS}	0.515	+34.4%	0.010	0.34%	XPS emissivity
ϵ_{tp}	0.890	+41.3%	0.015	0.62%	tape emissivity
Ω_{tp}	0.540	+28.1%	0.020	0.56%	tape coverage
ϵ_{rs}	0.040	+143%	0.010	1.43%	test-surface emissivity
ϵ_{wt}	0.900	+67.5%	0.025	1.69%	wind-tunnel emissivity
				4.27%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	41.9r/min	+0.183%/(r/min)	5.4r/min	0.98%	fan rotation rate
				4.70%	RSS combined uncertainty



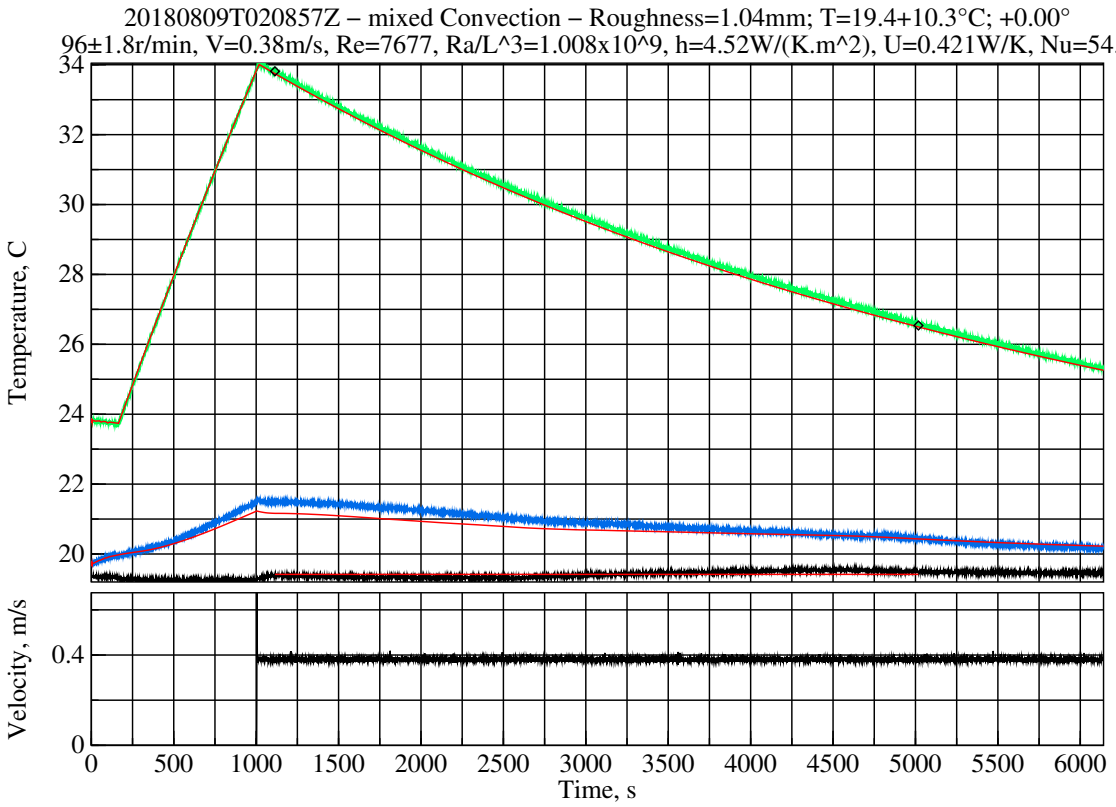
Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 4691$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	10.4K	+21.3%/K	0.10K	2.13%	LM35C differential
P	101kPa	+0.0008%/Pa	1.5kPa	1.13%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.045%/(J/K)	42J/K	1.91%	plate thermal capacity
C_V	1.000	−12.1%	0.100	1.21%	vertical reuptake
L_c	0.305m	+551%/m	500um	0.28%	characteristic length
D_{PIR}	25.4mm	−514%/m	1.0mm	0.51%	insulation thickness
D_g	1.00mm	−522%/m	500um	0.26%	air gap
L_m	3.57mm	+1190%/m	500um	0.59%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.511\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.57%	PIR thermal conductivity
ϵ_{XPS}	0.515	+33.3%	0.010	0.33%	XPS emissivity
ϵ_{tp}	0.890	+39.9%	0.015	0.60%	tape emissivity
Ω_{tp}	0.540	+27.1%	0.020	0.54%	tape coverage
ϵ_{rs}	0.040	+138%	0.010	1.38%	test-surface emissivity
ϵ_{wt}	0.900	+65.0%	0.025	1.63%	wind-tunnel emissivity
				4.18%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	57.9r/min	+0.295%/(r/min)	2.7r/min	0.80%	fan rotation rate
				4.47%	RSS combined uncertainty



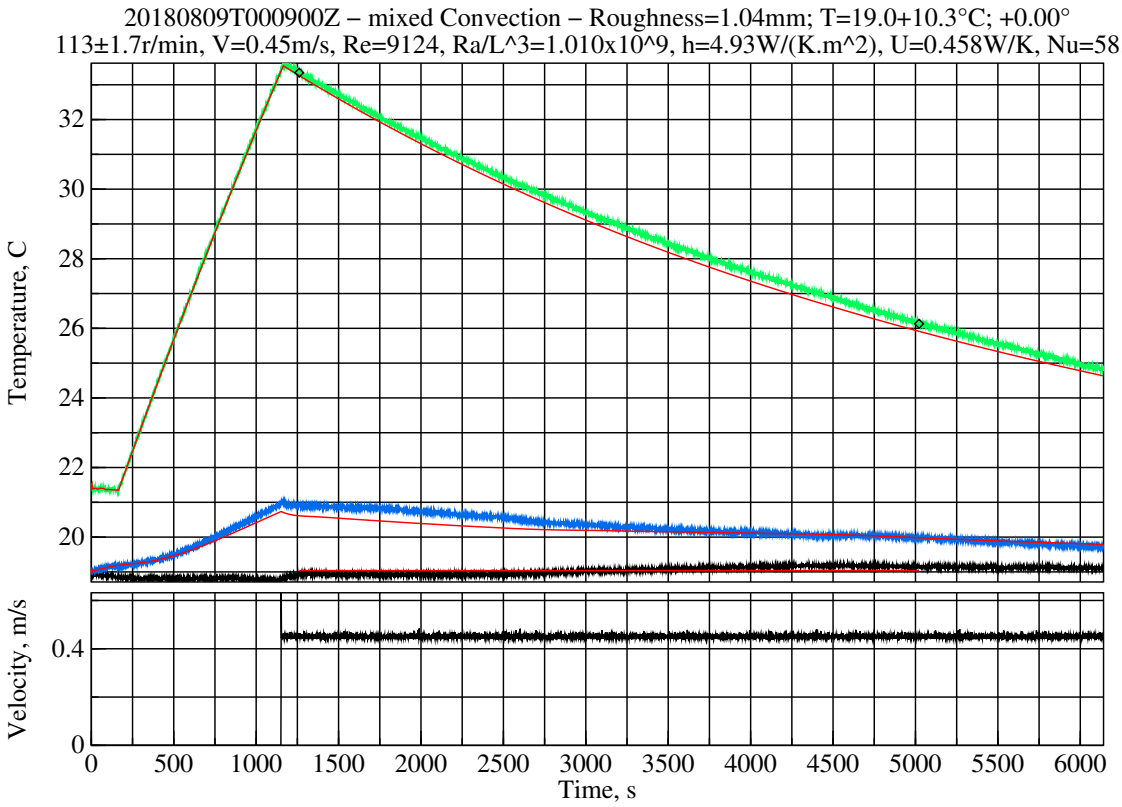
Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 6568$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	10.3K	+20.1%/K	0.10K	2.01%	LM35C differential
P	102kPa	+0.0009%/Pa	1.5kPa	1.33%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.043%/(J/K)	42J/K	1.84%	plate thermal capacity
η	0.450	+98.2%	0.004	0.44%	anemometer calibration
C_V	1.000	−11.0%	0.100	1.10%	vertical reuptake
L_c	0.305m	+558%/m	500um	0.28%	characteristic length
L_T	8.34mm	+2525%/m	100um	0.25%	post length
ς	2.00mm	−5969%/m	100um	0.60%	post height
D_{PIR}	25.4mm	−501%/m	1.0mm	0.50%	insulation thickness
D_g	1.00mm	−508%/m	500um	0.25%	air gap
L_m	3.57mm	+1141%/m	500um	0.57%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.500\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.55%	PIR thermal conductivity
ϵ_{XPS}	0.515	+30.1%	0.010	0.30%	XPS emissivity
ϵ_{tp}	0.890	+36.1%	0.015	0.54%	tape emissivity
Ω_{tp}	0.540	+24.5%	0.020	0.49%	tape coverage
ϵ_{rs}	0.040	+125%	0.010	1.25%	test-surface emissivity
ϵ_{wt}	0.900	+58.7%	0.025	1.47%	wind-tunnel emissivity
				4.06%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	80.7r/min	+0.548%/(r/min)	1.9r/min	1.06%	fan rotation rate
				4.58%	RSS combined uncertainty



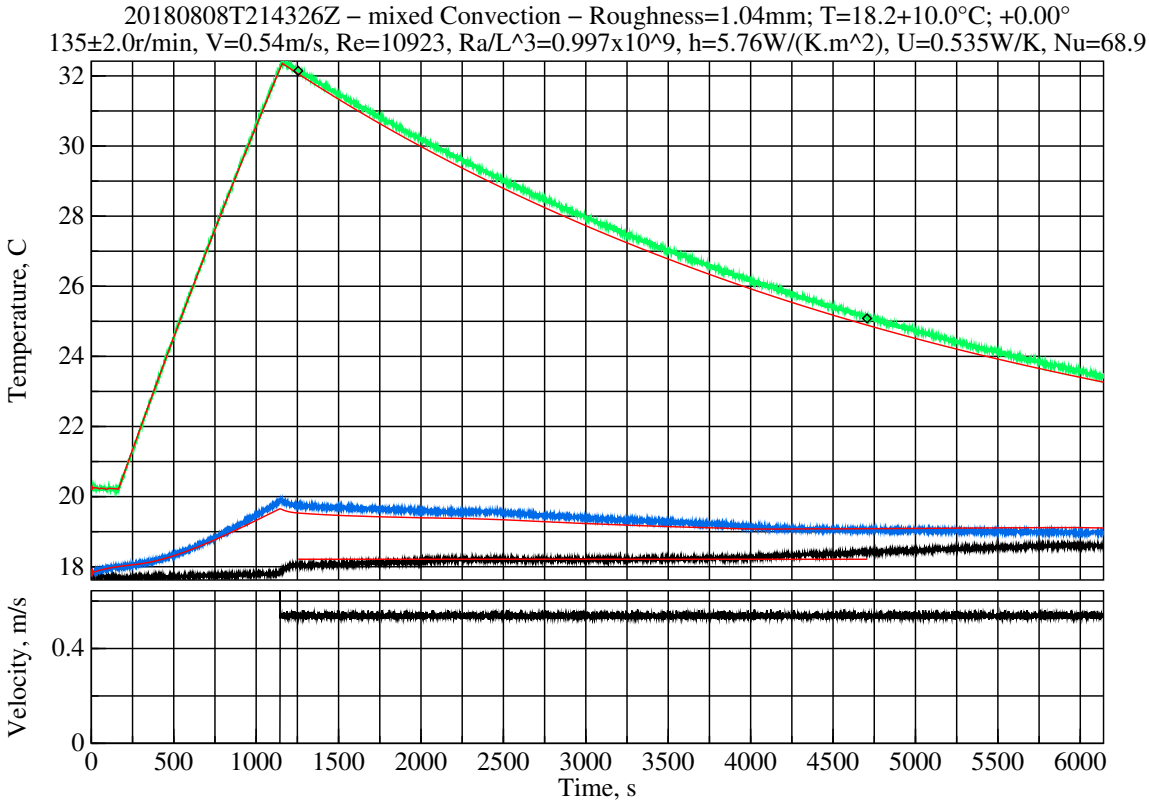
Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 7677$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	10.3K	+19.1%/K	0.10K	1.91%	LM35C differential
P	100kPa	+0.0010%/Pa	1.5kPa	1.49%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.042%/(J/K)	42J/K	1.78%	plate thermal capacity
η	0.450	+140%	0.004	0.63%	anemometer calibration
C_V	1.000	−10.2%	0.100	1.02%	vertical reuptake
L_c	0.305m	+548%/m	500um	0.27%	characteristic length
L_T	8.34mm	+3971%/m	100um	0.40%	post length
ς	2.00mm	−10138%/m	100um	1.01%	post height
D_{PIR}	25.4mm	−477%/m	1.0mm	0.48%	insulation thickness
D_g	1.00mm	−484%/m	500um	0.24%	air gap
L_m	3.57mm	+1094%/m	500um	0.55%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.477\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.53%	PIR thermal conductivity
ϵ_{XPS}	0.515	+27.7%	0.010	0.28%	XPS emissivity
ϵ_{tp}	0.890	+33.2%	0.015	0.50%	tape emissivity
Ω_{tp}	0.540	+22.6%	0.020	0.45%	tape coverage
ϵ_{rs}	0.040	+116%	0.010	1.16%	test-surface emissivity
ϵ_{wt}	0.900	+54.0%	0.025	1.35%	wind-tunnel emissivity
				4.04%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	95.5r/min	+0.660%/(r/min)	1.8r/min	1.18%	fan rotation rate
				4.68%	RSS combined uncertainty



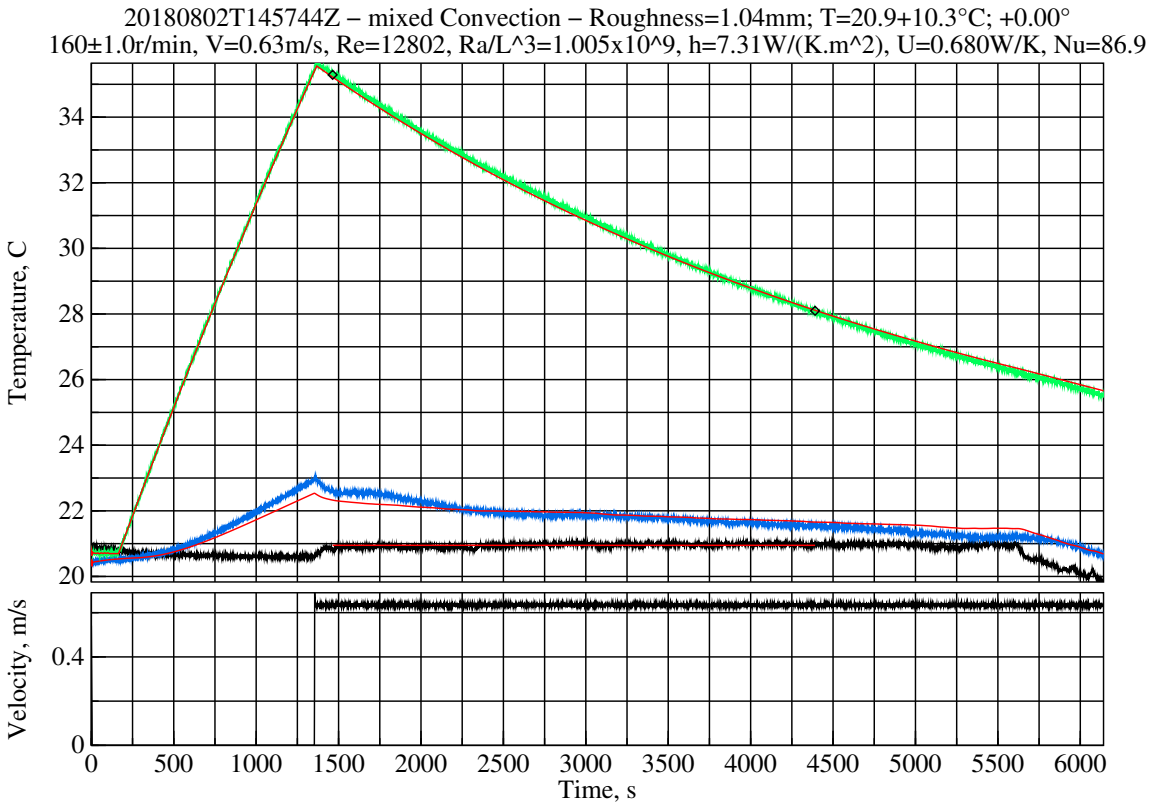
Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 9127$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	10.3K	+17.9%/K	0.10K	1.79%	LM35C differential
P	100kPa	+0.0011%/Pa	1.5kPa	1.60%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.040%/(J/K)	42J/K	1.69%	plate thermal capacity
η	0.450	+181%	0.004	0.82%	anemometer calibration
C_V	1.000	−9.00%	0.100	0.90%	vertical reuptake
L_c	0.305m	+512%/m	500um	0.26%	characteristic length
L_T	8.34mm	+5707%/m	100um	0.57%	post length
ς	2.00mm	−13474%/m	100um	1.35%	post height
D_{PIR}	25.4mm	−434%/m	1.0mm	0.43%	insulation thickness
D_g	1.00mm	−440%/m	500um	0.22%	air gap
L_m	3.57mm	+1011%/m	500um	0.51%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.435\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.48%	PIR thermal conductivity
ϵ_{XPS}	0.515	+24.4%	0.010	0.24%	XPS emissivity
ϵ_{tp}	0.890	+29.2%	0.015	0.44%	tape emissivity
Ω_{tp}	0.540	+19.9%	0.020	0.40%	tape coverage
ϵ_{rs}	0.040	+102%	0.010	1.02%	test-surface emissivity
ϵ_{wt}	0.900	+47.5%	0.025	1.19%	wind-tunnel emissivity
				3.99%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	113r/min	+0.720%/(r/min)	1.7r/min	1.21%	fan rotation rate
				4.67%	RSS combined uncertainty



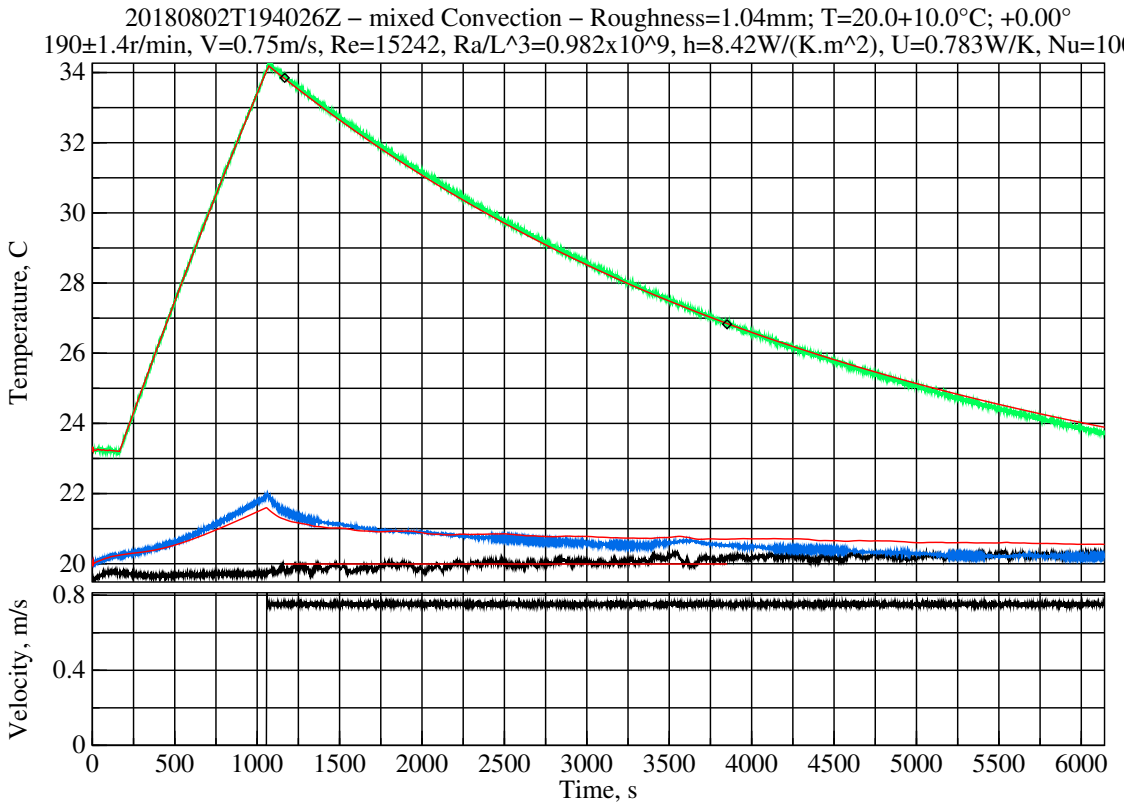
Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 10922$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	10.0K	+16.9%/K	0.10K	1.69%	LM35C differential
P	100kPa	+0.0011%/Pa	1.5kPa	1.64%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.037%/(J/K)	42J/K	1.59%	plate thermal capacity
η	0.450	+208%	0.004	0.94%	anemometer calibration
C_V	1.000	−7.68%	0.100	0.77%	vertical reuptake
L_c	0.305m	+449%/m	500um	0.22%	characteristic length
L_T	8.34mm	+7227%/m	100um	0.72%	post length
ς	2.00mm	−14582%/m	100um	1.46%	post height
D_{PIR}	25.4mm	−381%/m	1.0mm	0.38%	insulation thickness
L_m	3.57mm	+914%/m	500um	0.46%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.384\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.43%	PIR thermal conductivity
ϵ_{XPS}	0.515	+20.6%	0.010	0.21%	XPS emissivity
ϵ_{tp}	0.890	+24.8%	0.015	0.37%	tape emissivity
Ω_{tp}	0.540	+16.8%	0.020	0.34%	tape coverage
ϵ_{rs}	0.040	+86.3%	0.010	0.86%	test-surface emissivity
ϵ_{wt}	0.900	+40.2%	0.025	1.00%	wind-tunnel emissivity
				3.86%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	135r/min	+0.693%/(r/min)	2.0r/min	1.40%	fan rotation rate
				4.77%	RSS combined uncertainty



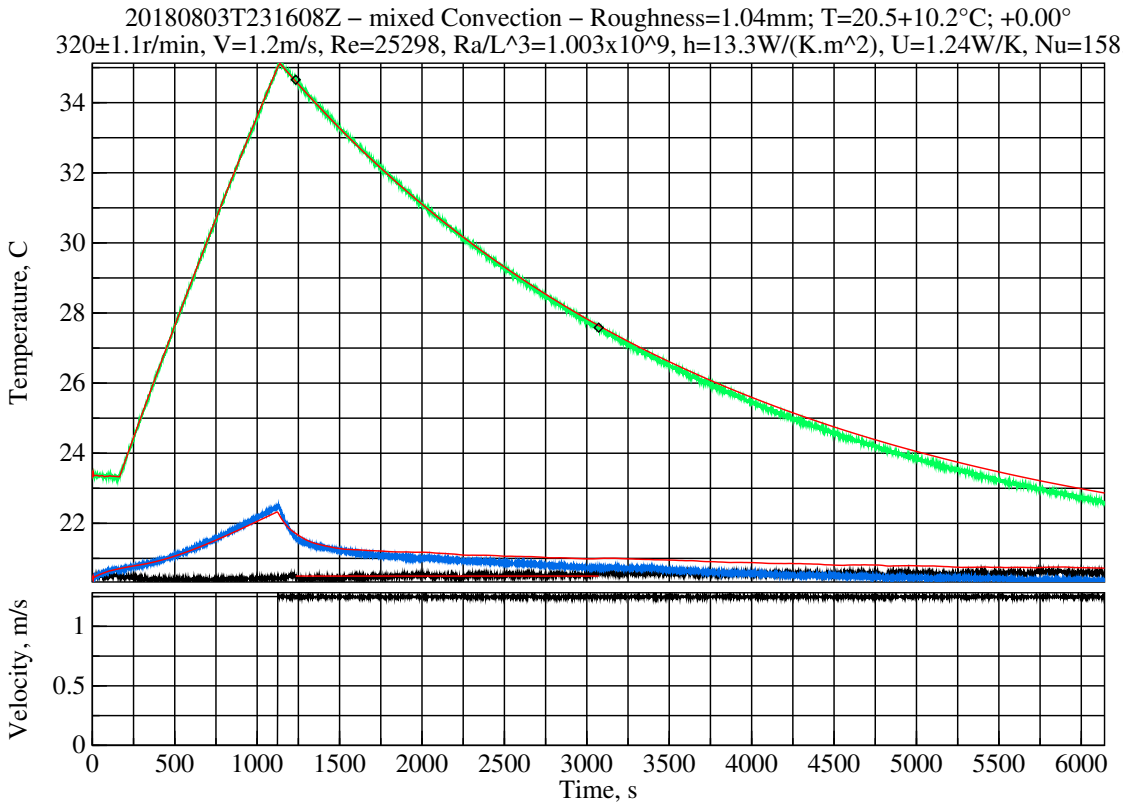
Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 12804$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	10.3K	+15.3%/K	0.10K	1.53%	LM35C differential
P	101kPa	+0.0011%/Pa	1.5kPa	1.60%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.036%/(J/K)	42J/K	1.51%	plate thermal capacity
η	0.450	+216%	0.004	0.97%	anemometer calibration
C_V	1.000	−6.61%	0.100	0.66%	vertical reuptake
L_T	8.34mm	+8070%/m	100um	0.81%	post length
ς	2.00mm	−13784%/m	100um	1.38%	post height
D_{PIR}	25.4mm	−332%/m	1.0mm	0.33%	insulation thickness
L_m	3.57mm	+841%/m	500um	0.42%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.336\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.37%	PIR thermal conductivity
ϵ_{tp}	0.890	+21.8%	0.015	0.33%	tape emissivity
Ω_{tp}	0.540	+14.8%	0.020	0.30%	tape coverage
ϵ_{rs}	0.040	+75.9%	0.010	0.76%	test-surface emissivity
ϵ_{wt}	0.900	+35.4%	0.025	0.88%	wind-tunnel emissivity
				3.64%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	160r/min	+0.607%/(r/min)	0.96r/min	0.58%	fan rotation rate
				3.83%	RSS combined uncertainty



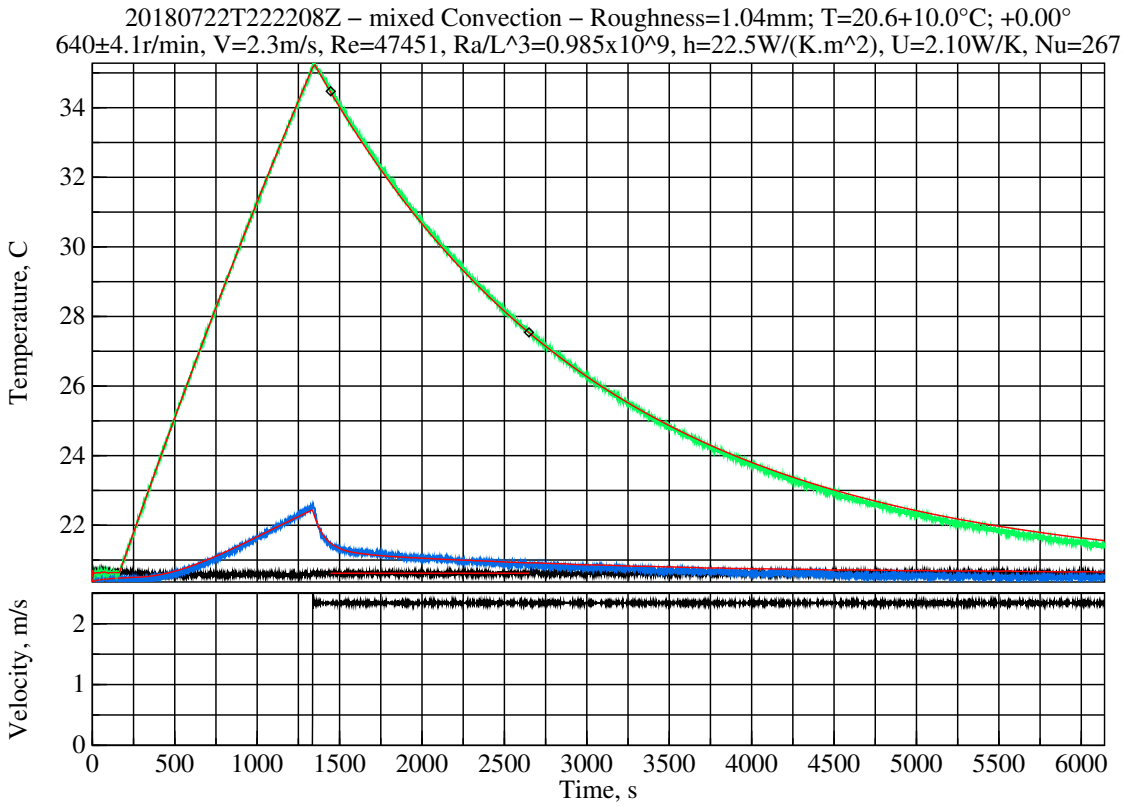
Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 15243$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	9.97K	+14.9%/K	0.10K	1.49%	LM35C differential
P	101kPa	+0.0010%/Pa	1.5kPa	1.55%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.034%/(J/K)	42J/K	1.43%	plate thermal capacity
η	0.450	+214%	0.004	0.96%	anemometer calibration
C_V	1.000	−5.56%	0.100	0.56%	vertical reuptake
L_T	8.34mm	+8611%/m	100um	0.86%	post length
ς	2.00mm	−12031%/m	100um	1.20%	post height
D_{PIR}	25.4mm	−287%/m	1.0mm	0.29%	insulation thickness
L_m	3.57mm	+763%/m	500um	0.38%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.291\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.32%	PIR thermal conductivity
ϵ_{tp}	0.890	+18.2%	0.015	0.27%	tape emissivity
Ω_{tp}	0.540	+12.4%	0.020	0.25%	tape coverage
ϵ_{rs}	0.040	+63.6%	0.010	0.64%	test-surface emissivity
ϵ_{wt}	0.900	+29.5%	0.025	0.74%	wind-tunnel emissivity
				3.41%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	190r/min	+0.507%/(r/min)	1.4r/min	0.73%	fan rotation rate
				3.71%	RSS combined uncertainty



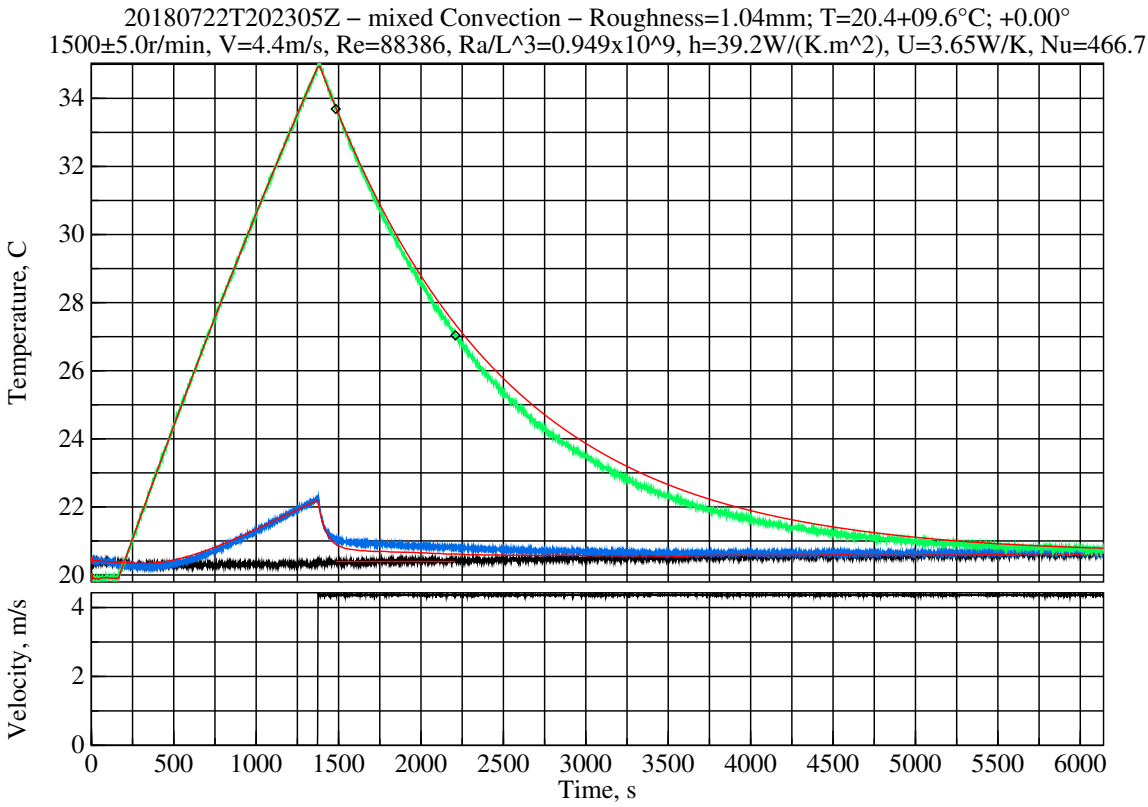
Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 25299$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	10.2K	+12.8%/K	0.10K	1.28%	LM35C differential
P	101kPa	+0.0009%/Pa	1.5kPa	1.37%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.030%/(J/K)	42J/K	1.28%	plate thermal capacity
η	0.450	+192%	0.004	0.86%	anemometer calibration
C_V	1.000	−3.48%	0.100	0.35%	vertical reuptake
L_T	8.34mm	+9160%/m	100um	0.92%	post length
ς	2.00mm	−6766%/m	100um	0.68%	post height
L_m	3.57mm	+613%/m	500um	0.31%	side metal strip width
k_{PIR}	$22.2\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$+0.193\%/\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	$1.1\frac{\mathrm{mW}}{\mathrm{K\cdot m}}$	0.21%	PIR thermal conductivity
ϵ_{rs}	0.040	+39.9%	0.010	0.40%	test-surface emissivity
ϵ_{wt}	0.900	+18.4%	0.025	0.46%	wind-tunnel emissivity
				2.83%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	320r/min	+0.269%/(r/min)	1.1r/min	0.29%	fan rotation rate
				2.89%	RSS combined uncertainty



Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 47451$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	10.0K	+11.8%/K	0.10K	1.18%	LM35C differential
P	101kPa	+0.0008%/Pa	1.5kPa	1.25%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.028%/(J/K)	42J/K	1.17%	plate thermal capacity
η	0.450	+156%	0.004	0.70%	anemometer calibration
u_u	5.879	+2.25%	0.100	0.22%	diffuser airflow upper bound
C_V	1.000	−2.03%	0.100	0.20%	vertical reuptake
L_T	8.34mm	+9332%/m	100um	0.93%	post length
ς	2.00mm	−2623%/m	100um	0.26%	post height
L_m	3.57mm	+527%/m	500um	0.26%	side metal strip width
ϵ_{rs}	0.040	+23.4%	0.010	0.23%	test-surface emissivity
ϵ_{wt}	0.900	+10.7%	0.025	0.27%	wind-tunnel emissivity
				2.47%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	640r/min	+0.110%/(r/min)	4.1r/min	0.45%	fan rotation rate
				2.63%	RSS combined uncertainty



Estimated measurement uncertainties, bi-level 1mm roughness at $Re = 88388$.

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
ΔT	9.64K	+11.6%/K	0.10K	1.16%	LM35C differential
P	101kPa	+0.0008%/Pa	1.5kPa	1.19%	MPXH6115A6U air pressure
C_{pt}	4.24kJ/K	+0.026%/(J/K)	42J/K	1.11%	plate thermal capacity
η	0.450	+79.5%	0.004	0.36%	anemometer calibration
u_u	5.879	+7.46%	0.100	0.75%	diffuser airflow upper bound
L_T	8.34mm	+9395%/m	100um	0.94%	post length
L_m	3.57mm	+490%/m	500um	0.25%	side metal strip width
				2.39%	combined bias uncertainty
Symbol	**Nominal**	**Sensitivity**	**Variability**	**Uncertainty**	**Component**
ω	1.50kr/min	+0.040%/(r/min)	5.0r/min	0.20%	fan rotation rate
				2.43%	RSS combined uncertainty