Collaborative Testing Challenge
Plots of Collective Results

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2022 Symposium on Turbulence Modeling: Roadblocks, and the Potential for Machine Learning

Introduction

- This collaborative challenge was intended as a friendly learning exercise, not a competition

- Here all results are identified and plotted together; this helps provide a feel for the quality of the collective results
  - For comparison against a "standard" model, they are also plotted against SA results

- Everyone had difficulties – there are no winners or losers

- There's much to learn – both from successes and "failures"

Challenge Participants – what was submitted

(Green=submitted ; Red = not submitted)

Participant	2DZP	2DFDC	ASJ	2DWMH	2DN00
Fang (exp)	🟩	🟩	🟩	🟩	🟩
Fang (theory)	🟩	🟩	🟩	🟩	🟩
Bin	🟩	🟩	🟩	🟩	🟩
Cherroud	🟩	🟩	🟩	🟩	🟩
Dwight	🟩	🟩	🟩	🟩	🟩
Parish	🟩	🟩	🟩	🟩	🟩
Stoellinger	🟩	🟩	🟥	🟩	🟩
Viswanathan	🟩	🟩	🟥	🟩	🟥
Marepally	🟥	🟥	🟥	🟥	🟥

Zero-pressure gradient flat plate

High Re fully-developed channel

Axisymmetric jet
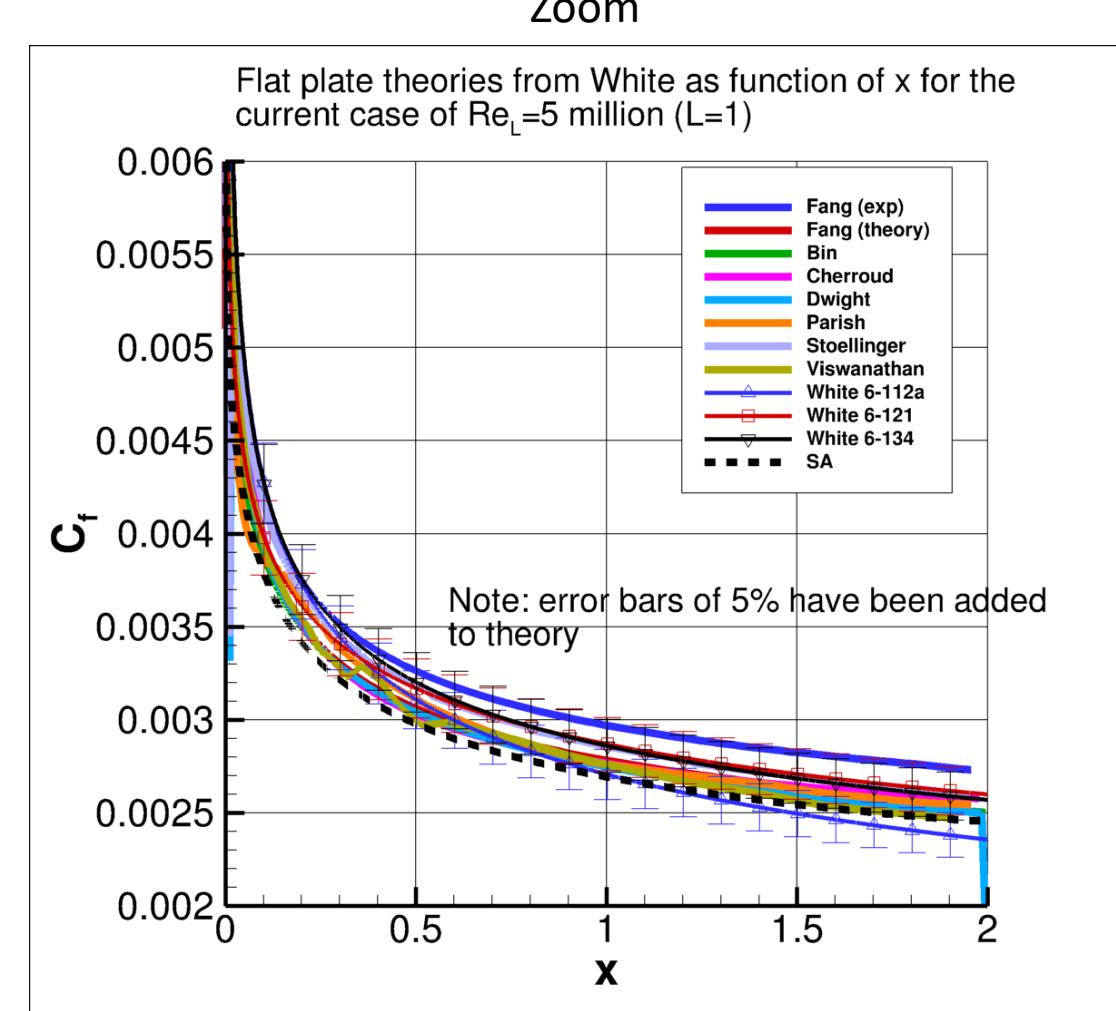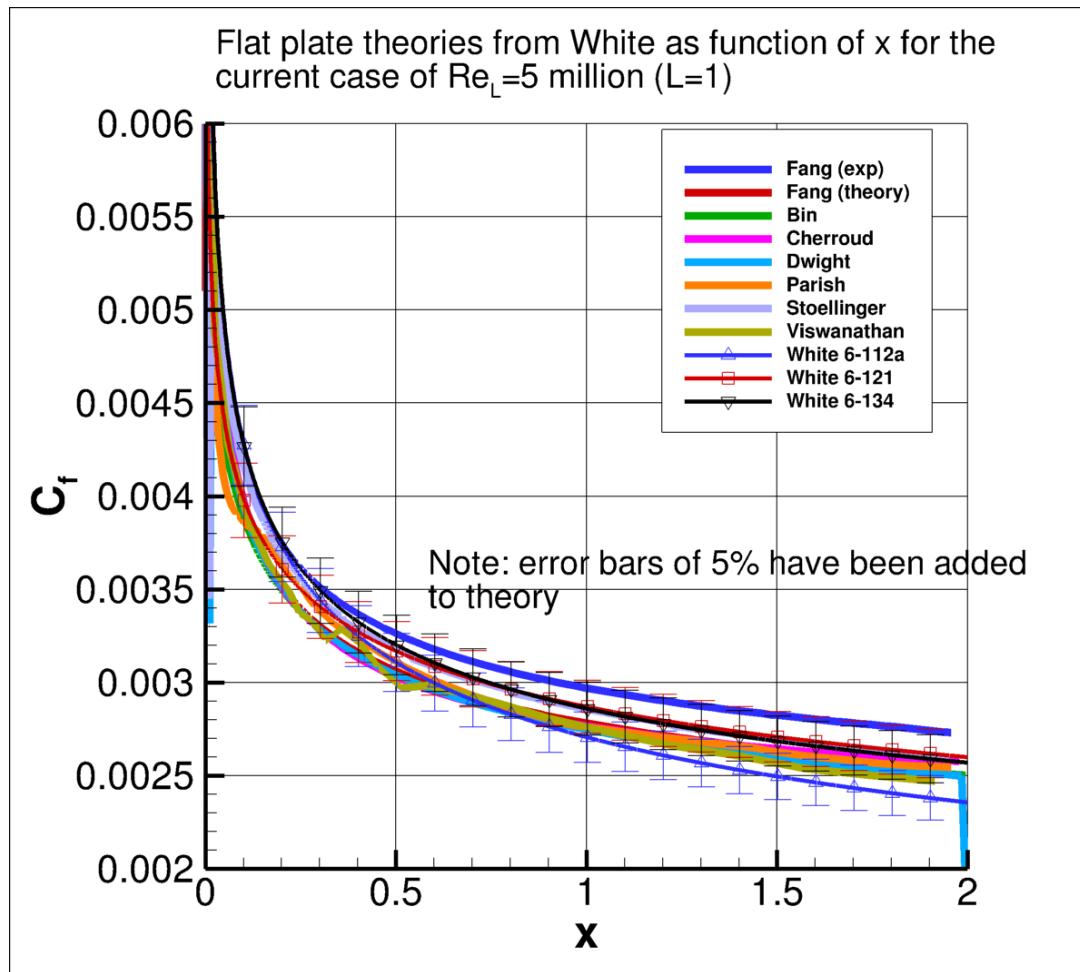
NASA wall-mounted hump

NACA 0012
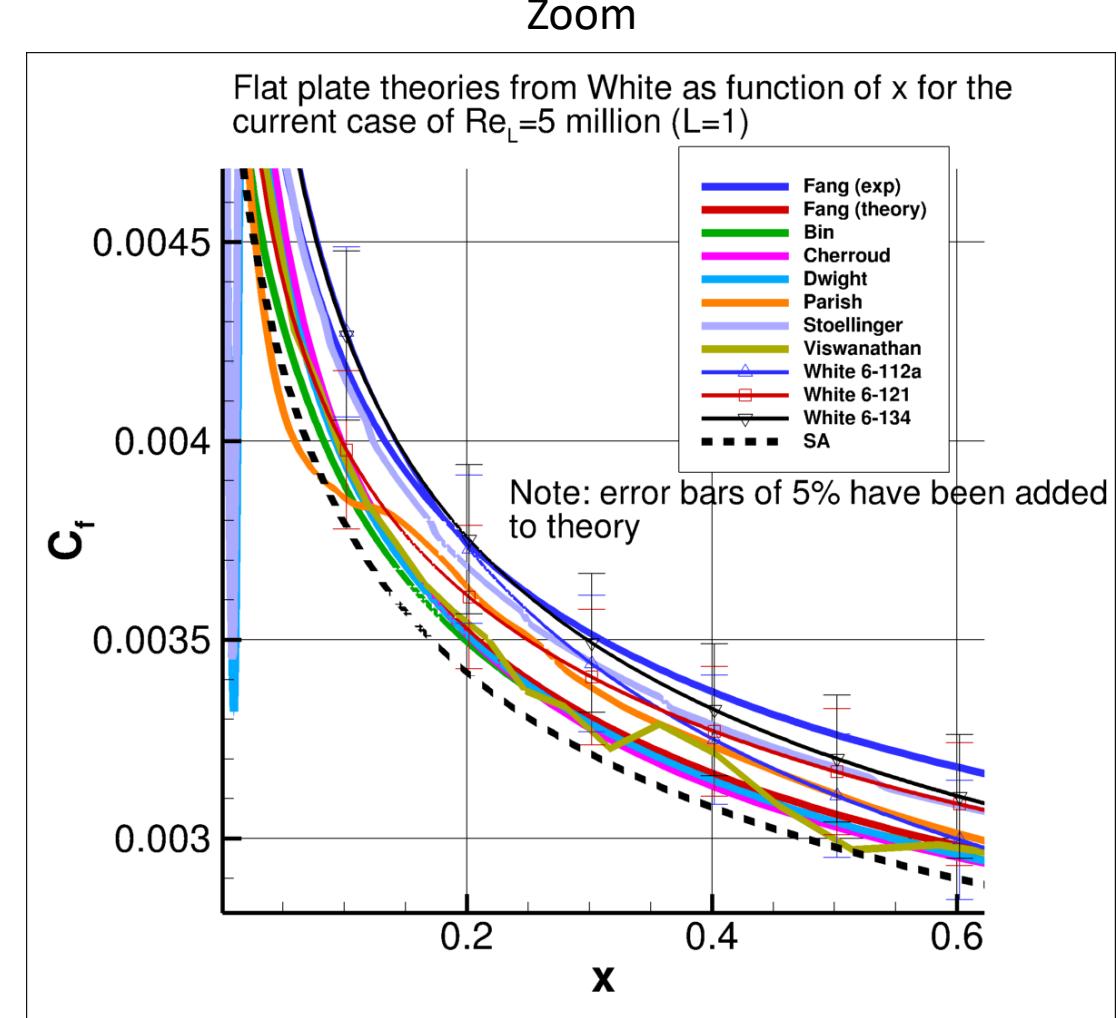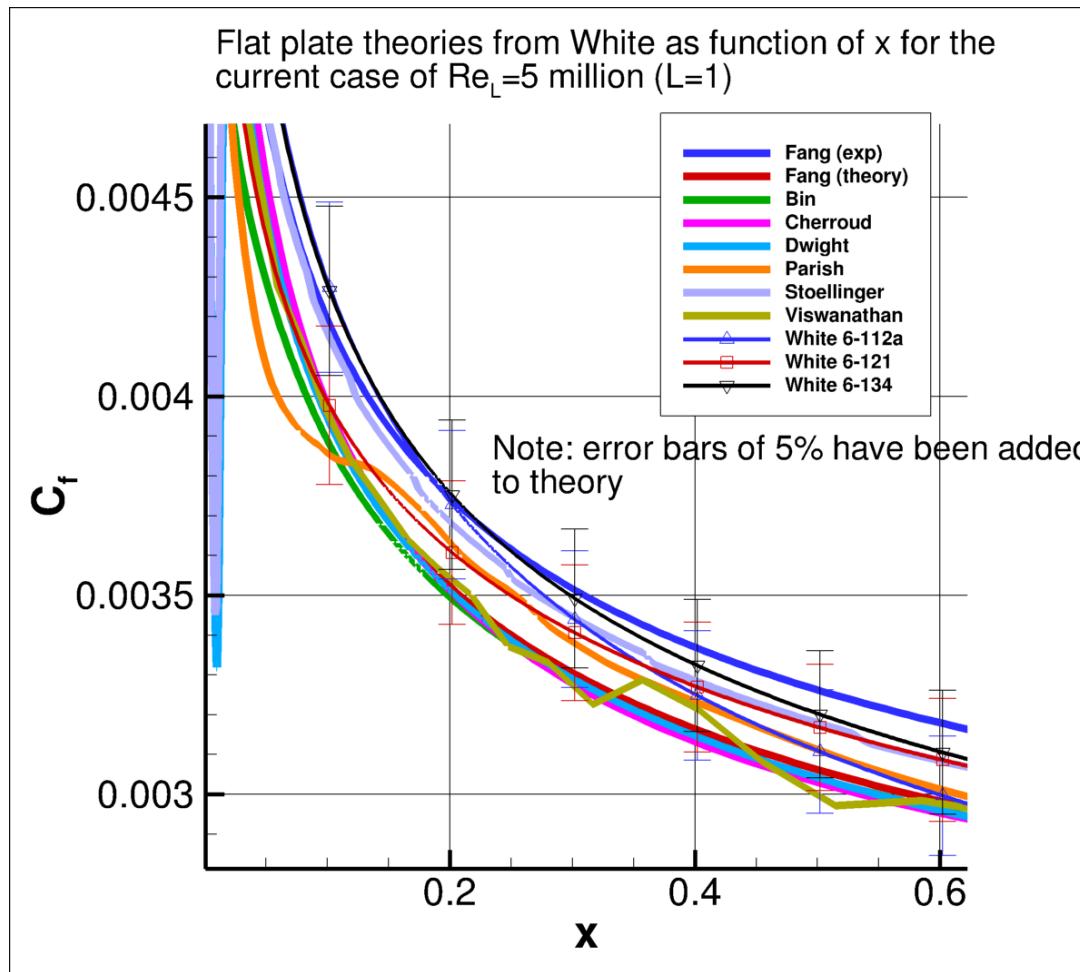
Challenge Participants – very brief summary of methods

Participant	Method
Fang (exp)	Gene Expression Programming (GEP) optimized based on experiment
Fang (theory)	GEP optimized based on theory
Bin	Data driven fix of SA model (do no harm… protect law of the wall)
Cherroud	Separately trained EARSM models aggregated
Dwight	Baseline SST model… then trained a classifier model
Parish	Ensemble of Neural Networks (NNs) with training data other than challenge cases
Stoellinger	Human-trained model
Viswanathan	Ground truth: SA model itself
Marepally	Field Inversion Machine Learning (FIML) on SA model (S809 airfoil for training)

2DZP

Flat plate theories from White as function of x for the current case of $Re_L=5$ million (L=1)

Zoom

2DZP

Zoom
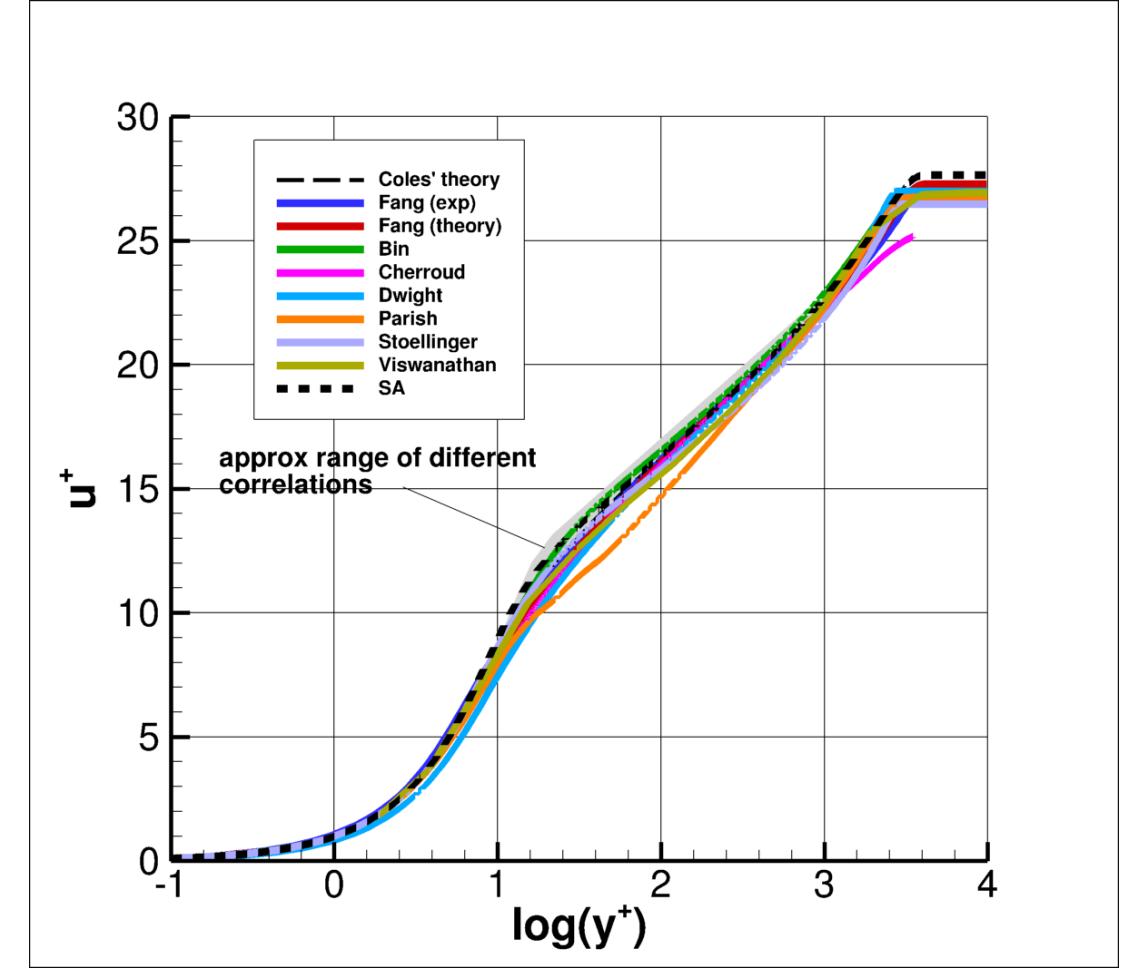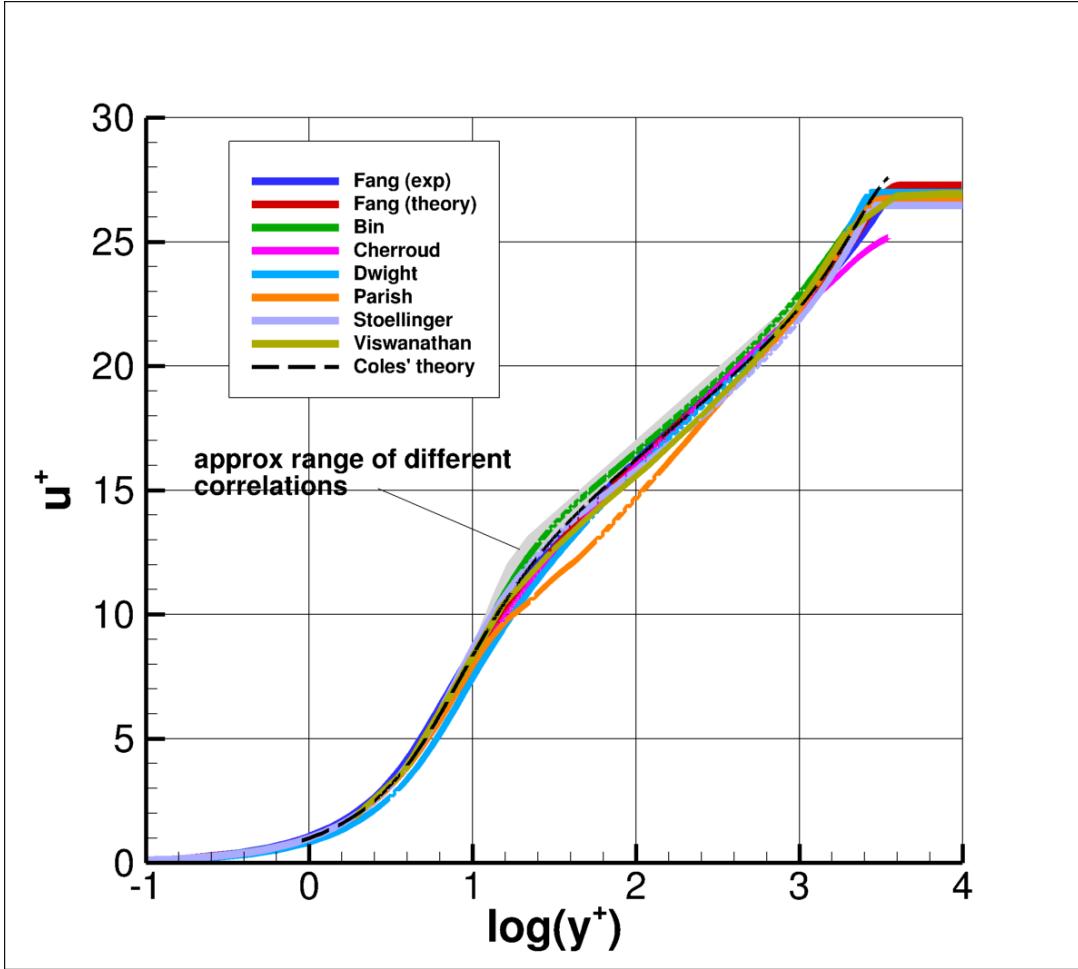
A few of the CFD results are "wavy"

2DZP
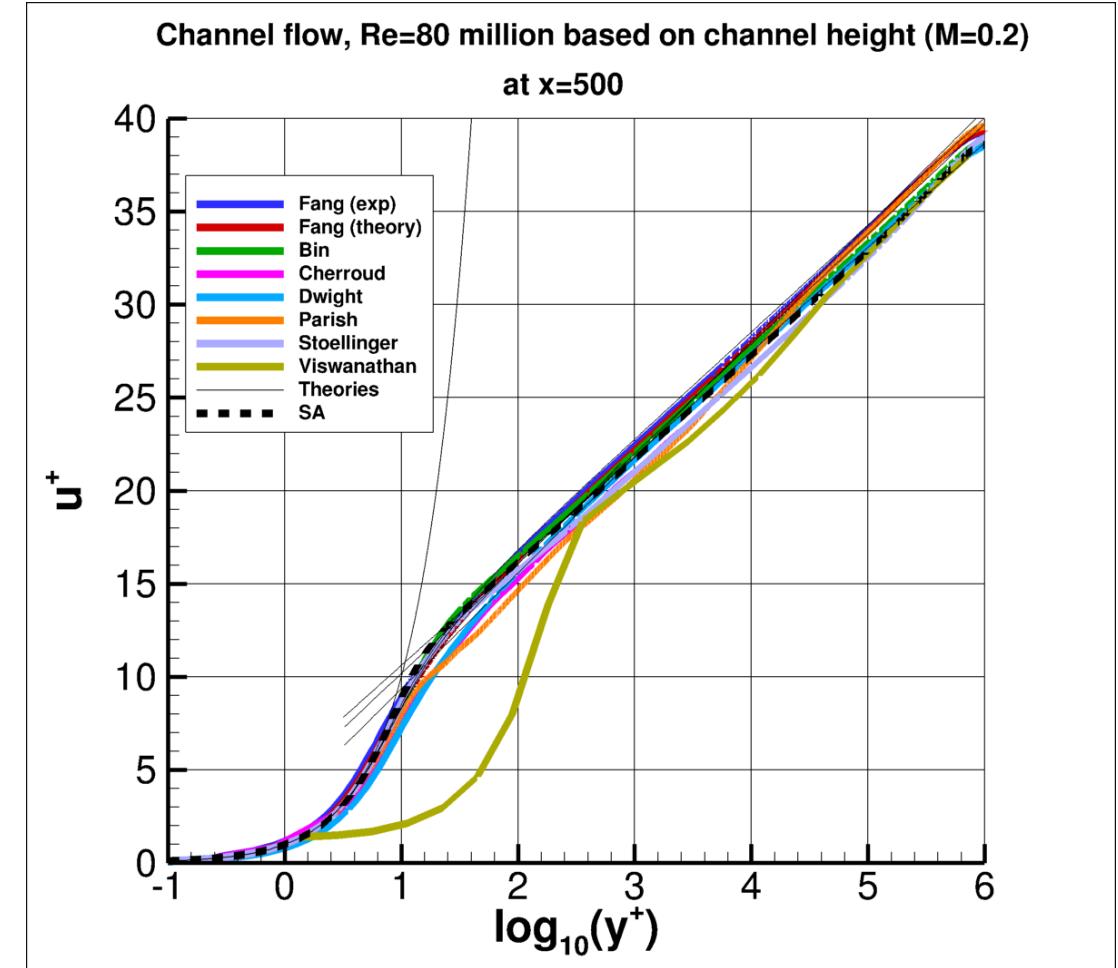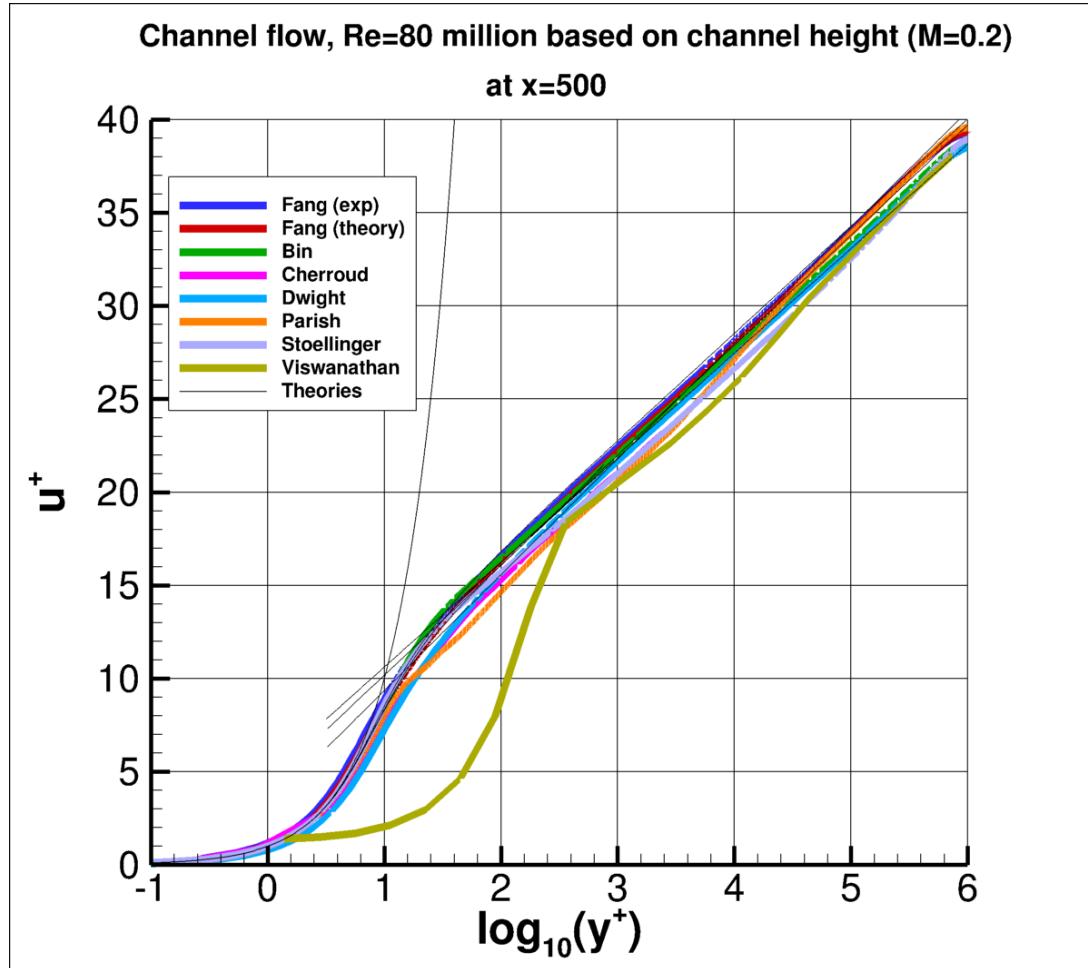
Parish departs from standard LOTW behavior

2DFDC

Channel flow, Re=80 million based on channel height (M=0.2) at x=500

Channel flow, Re=80 million based on channel height (M=0.2) at x=500
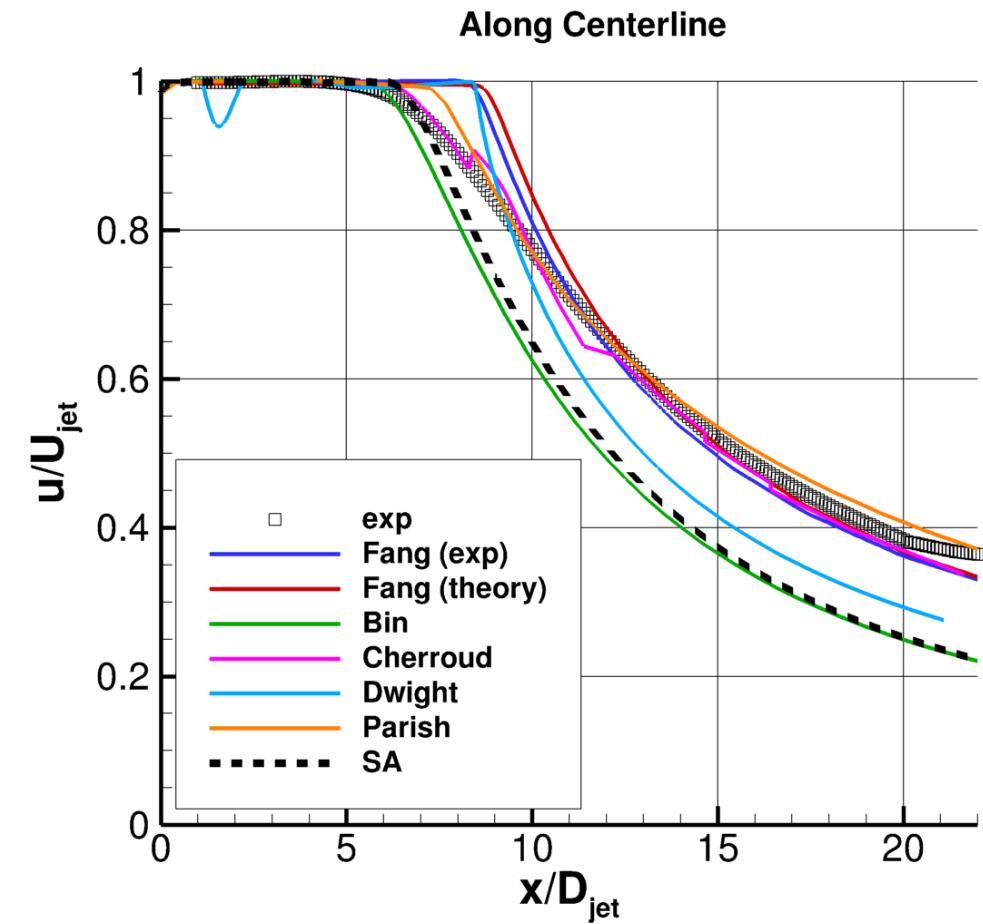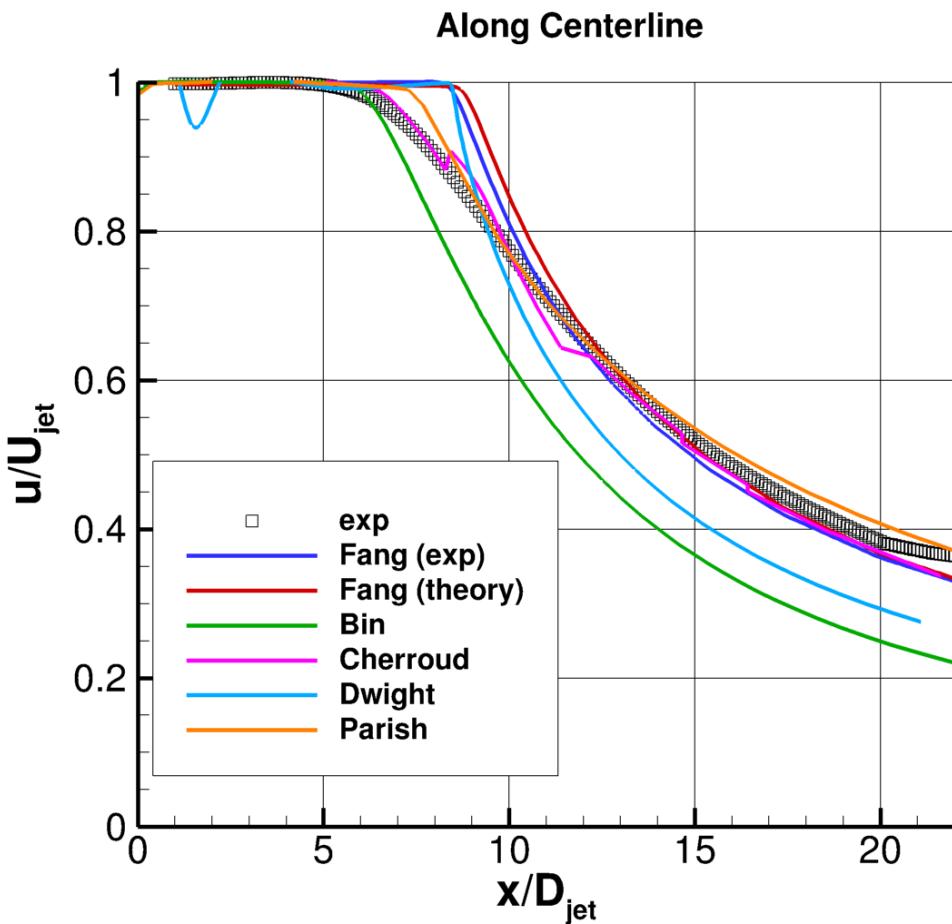
Parish (slightly) and Viswanathan depart from standard LOTW behavior

ASJ
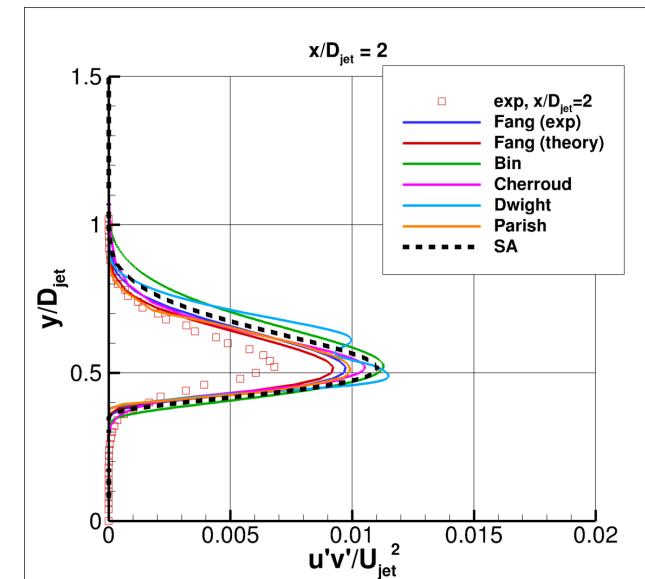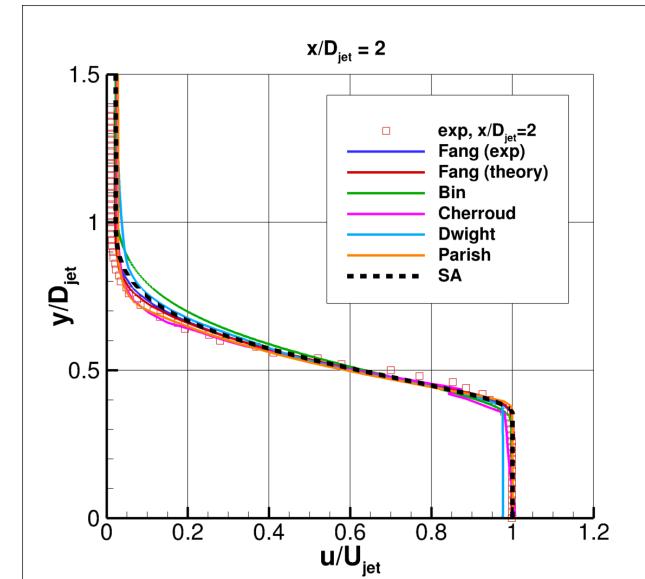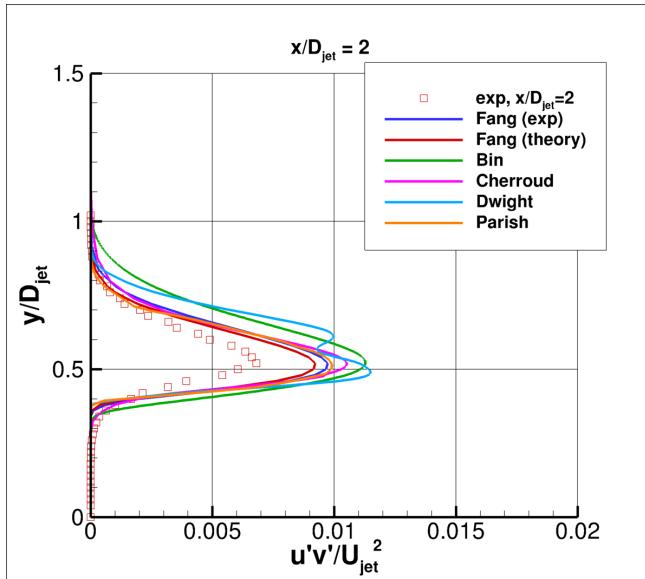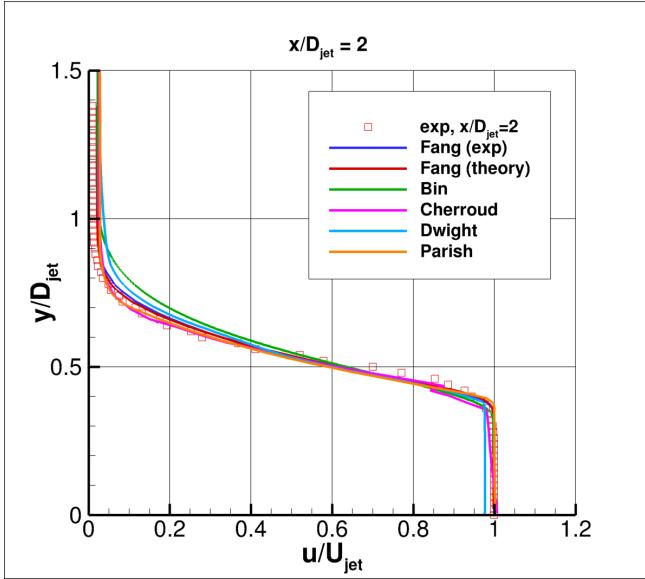
Parish and Cherroud are closest to data
(Cherroud has some "kinks"); Fang (exp) and Fang (theory) are
both close beyond $x/D_{jet}=12$

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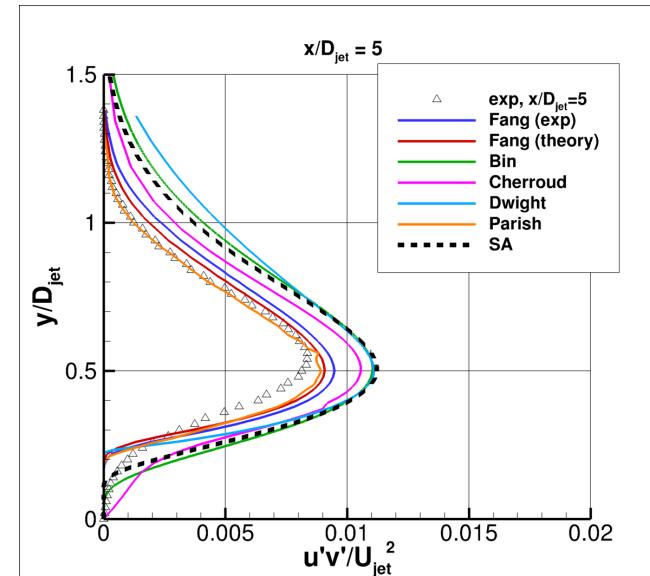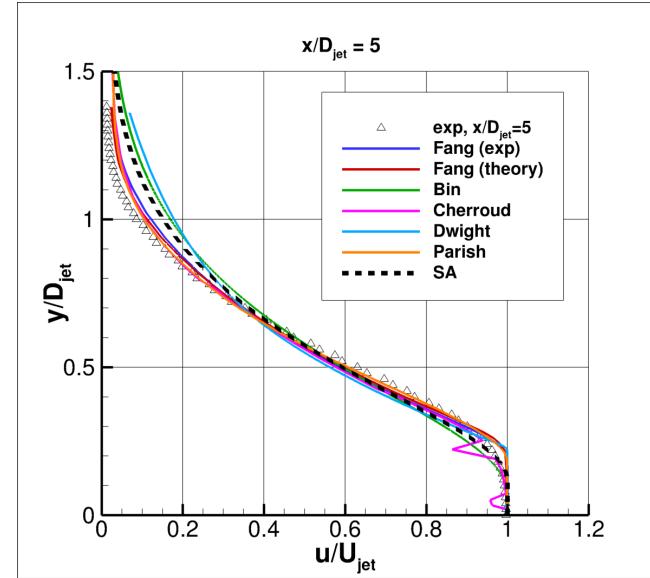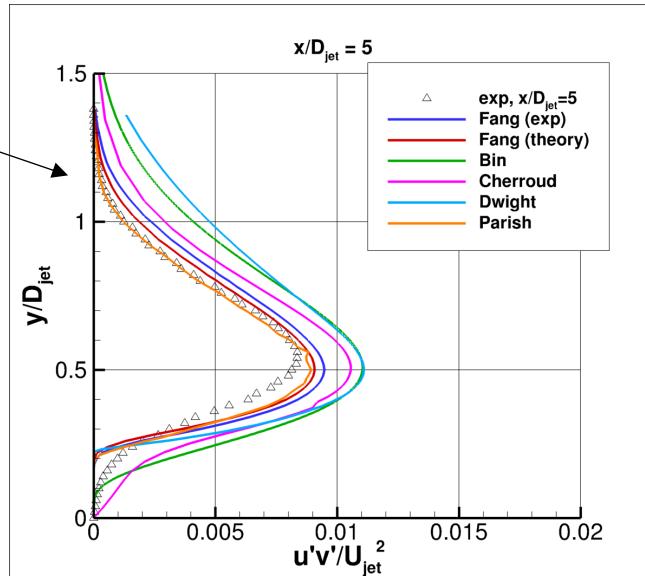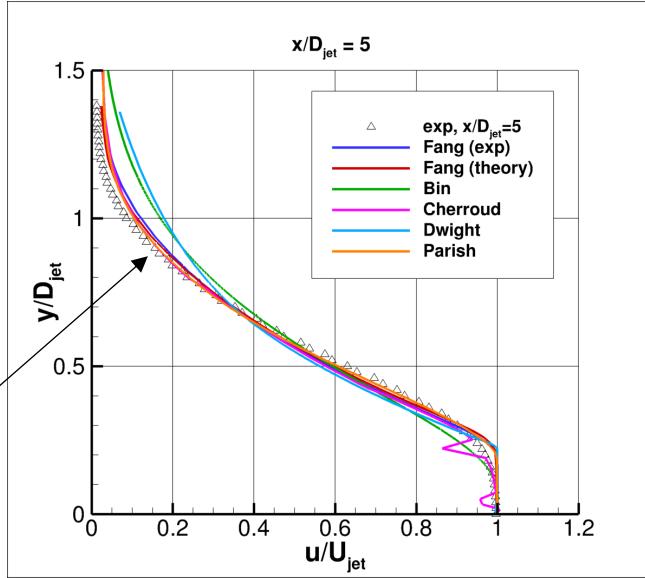
ASJ, at x/D$_{jet}$=2

How new results stack up against standard SA model

ASJ, at x/D$_{jet}$=5
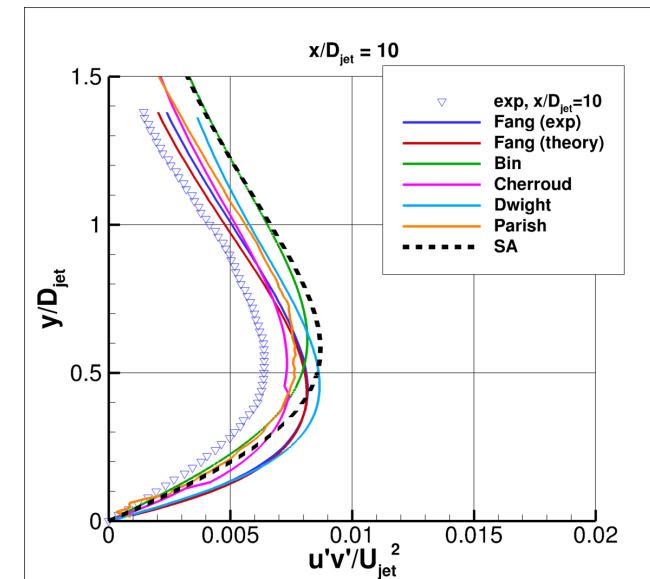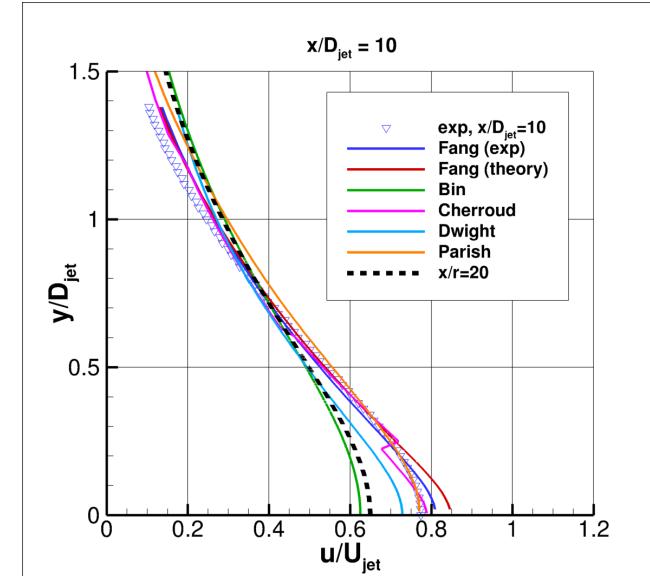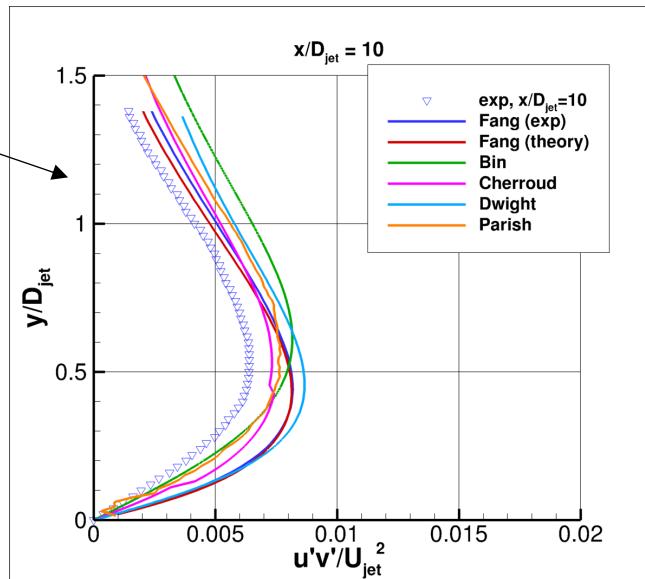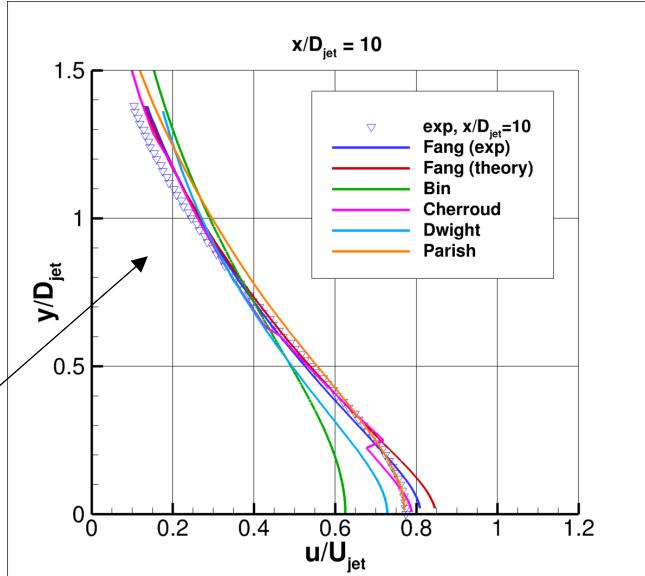
Fang (exp), Fang (theory), Cherroud, and Parish are all close to exp (some kinks in Cherroud, and Cherroud's u'v' is too large)

ASJ, at x/D$_{jet}$=10

How new results stack up against standard SA model
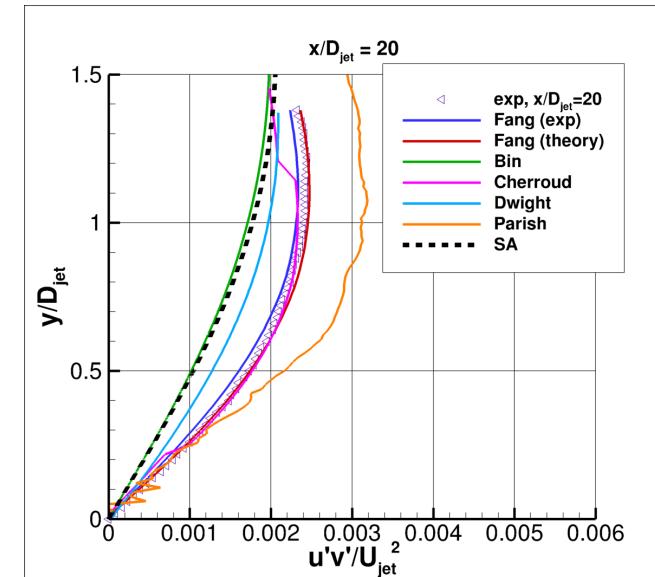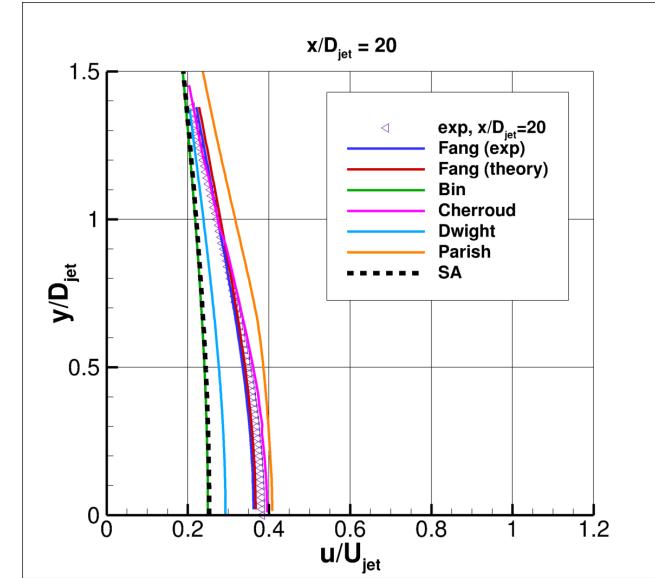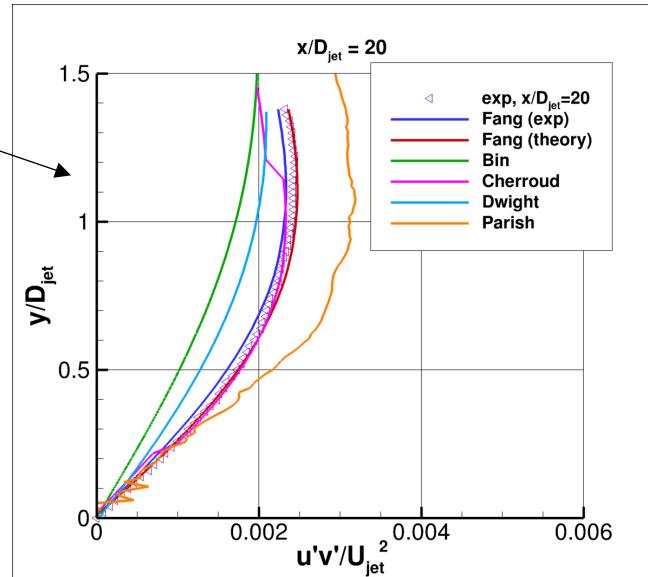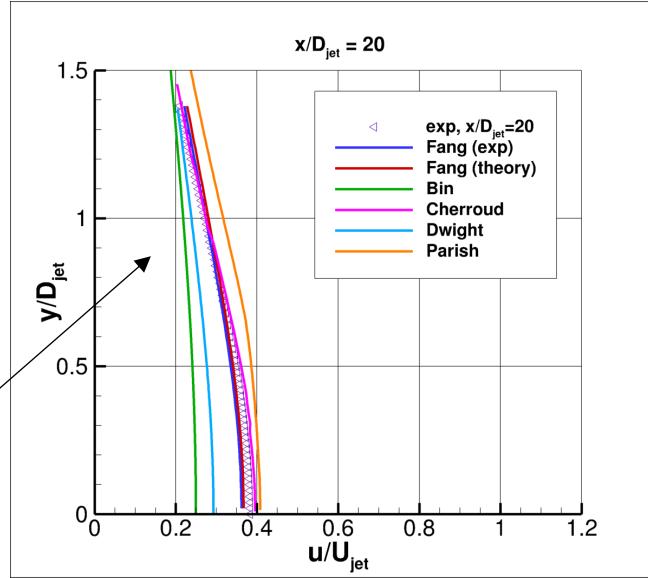
Fang (exp) and Cherroud are closest to exp (some kinks in Cherroud); Parish is close near y=0

ASJ, at x/D$_{jet}$=20
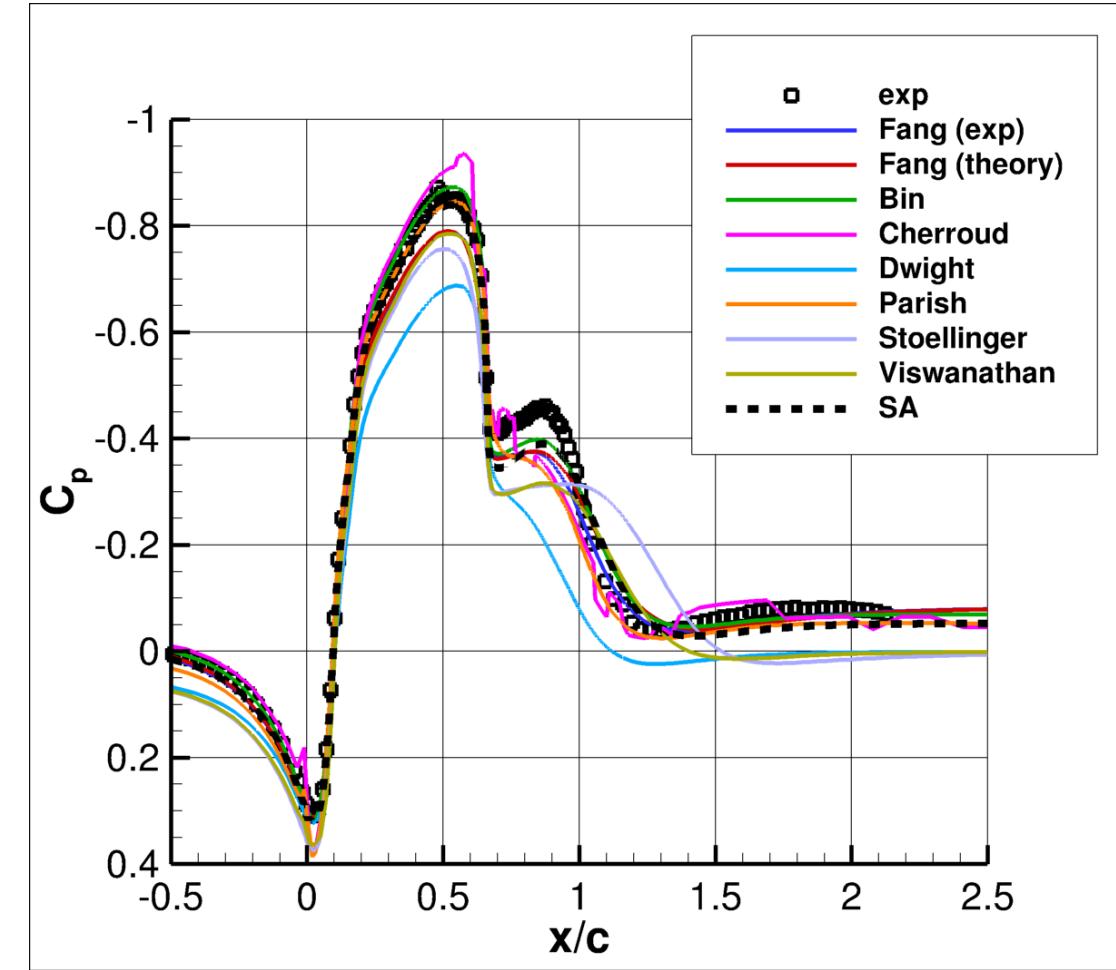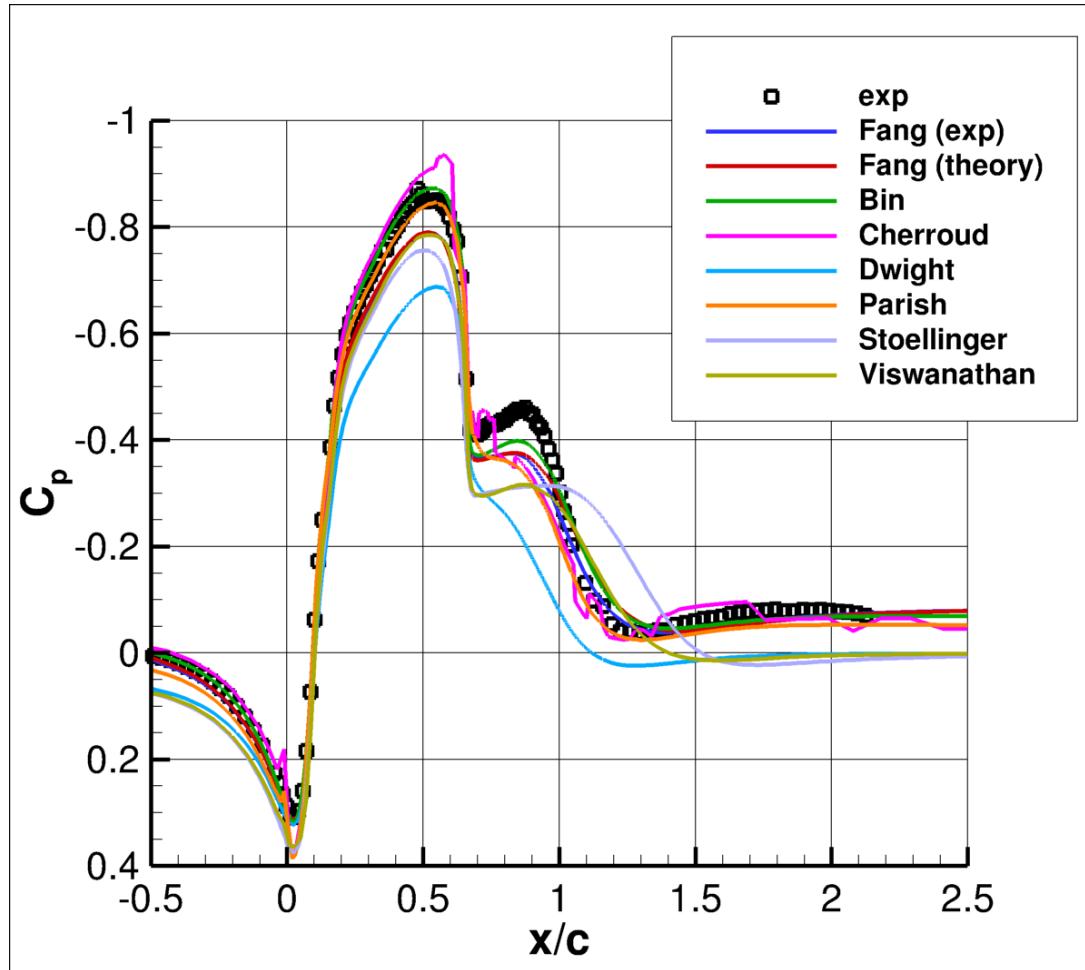
How new results stack up against standard SA model

Fang (exp), Fang (theory), and Cherroud are closest to exp); Parish is close near y=0 (but nonsmooth in u'v')

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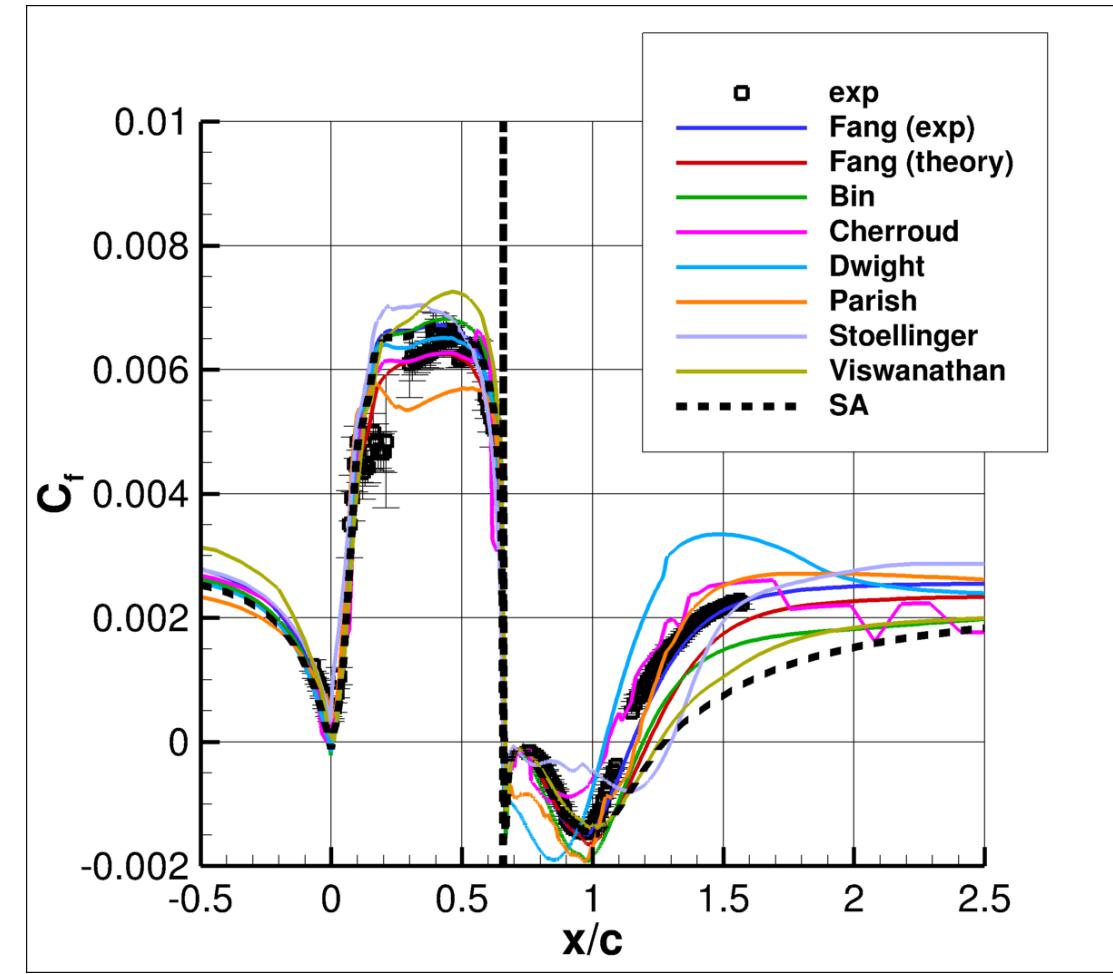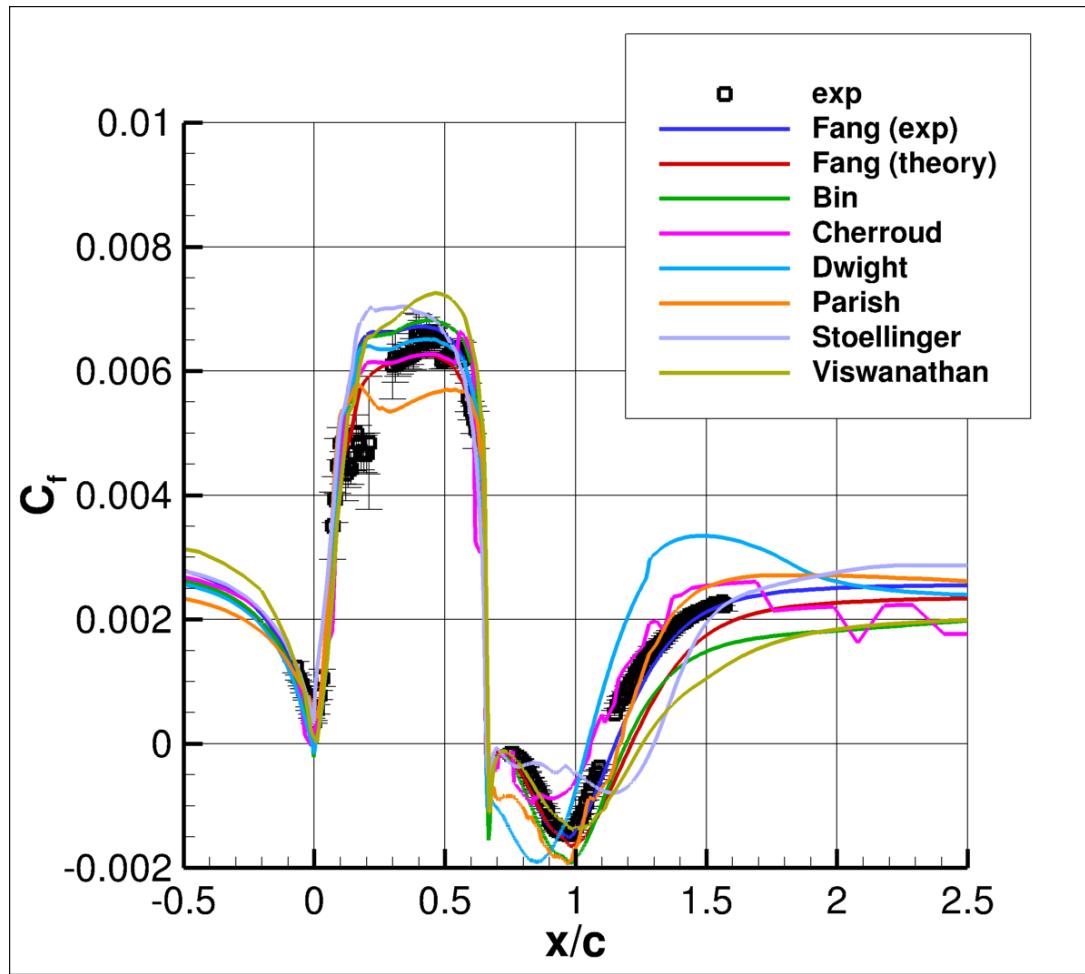
2DWMH

SA and Bin results look best
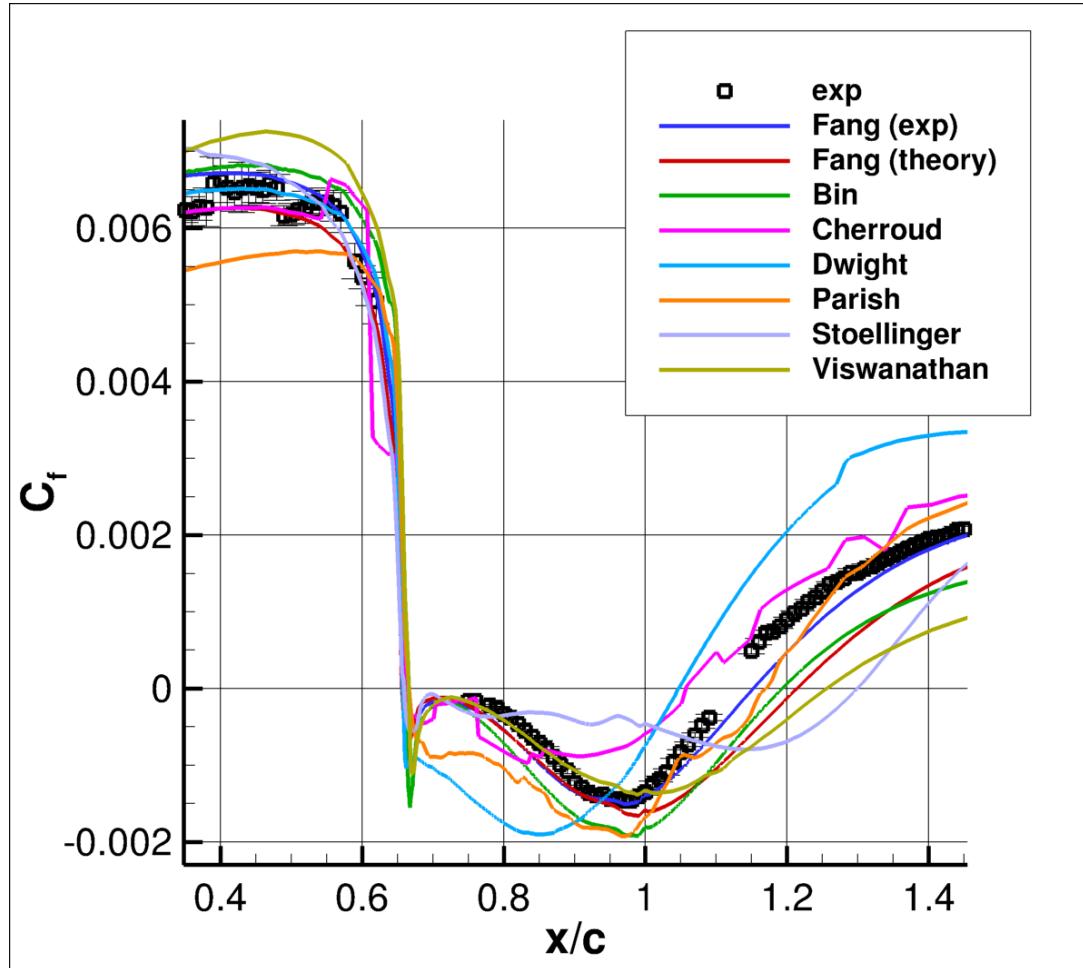
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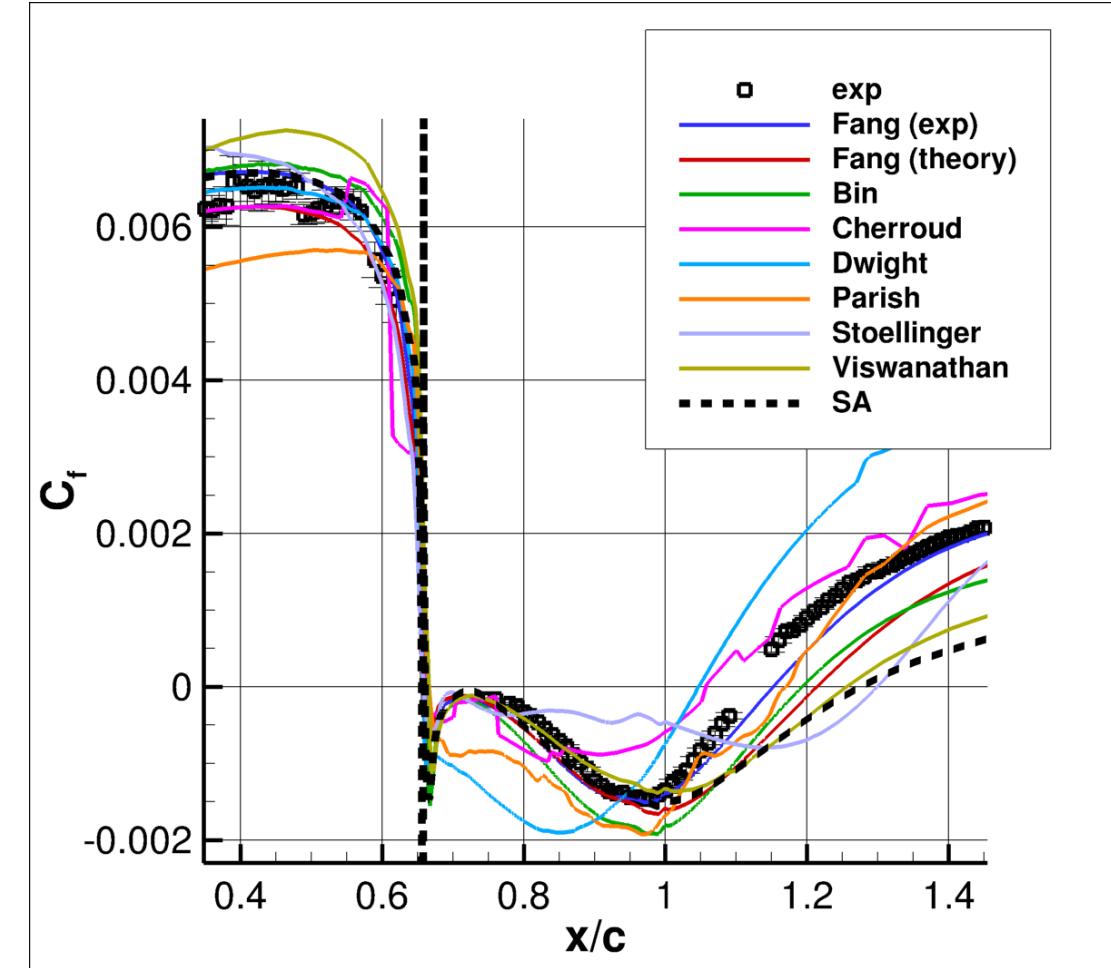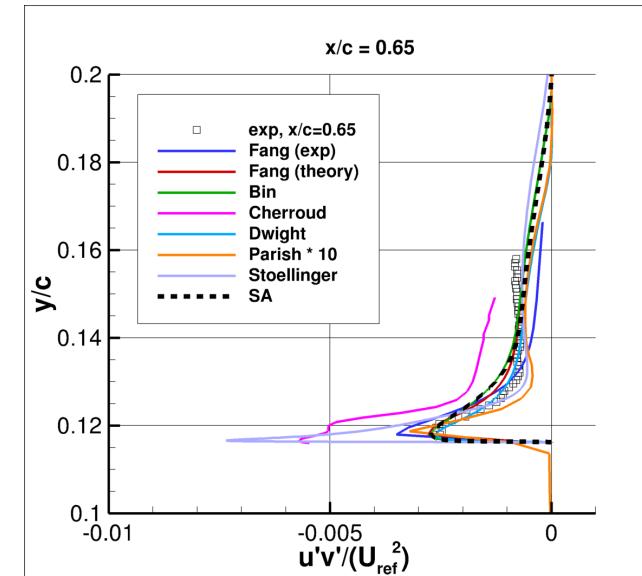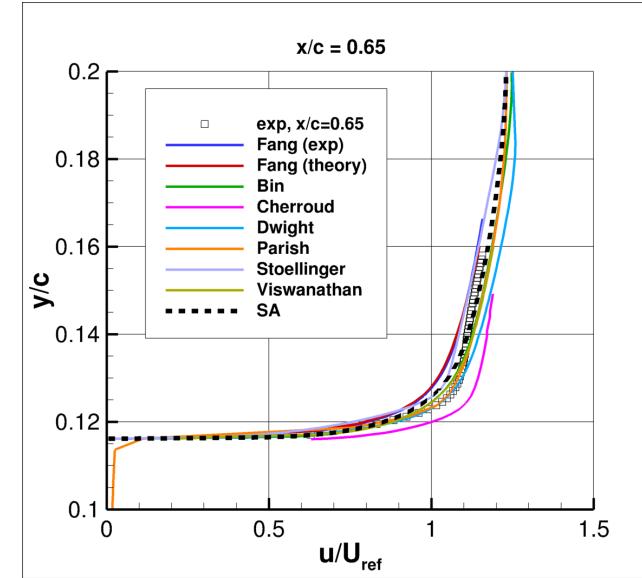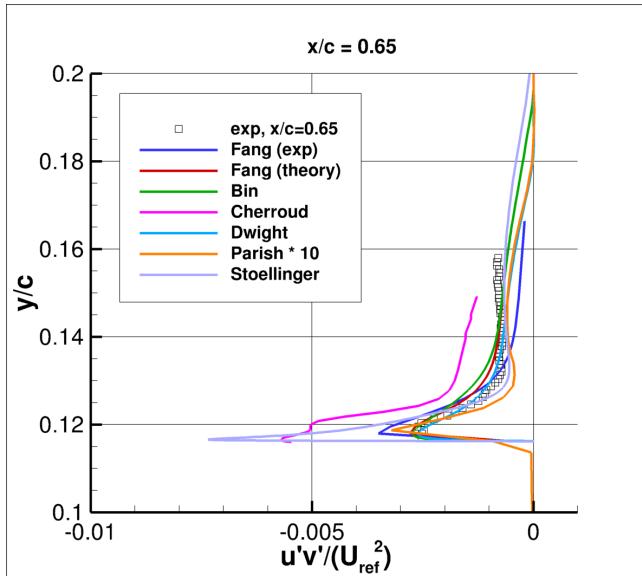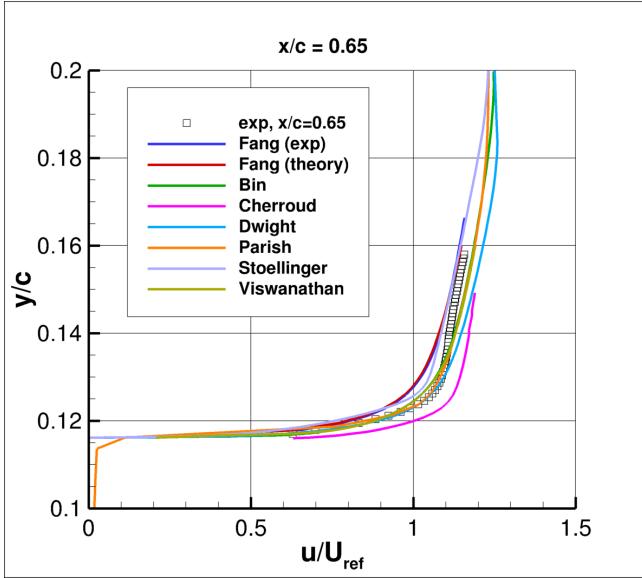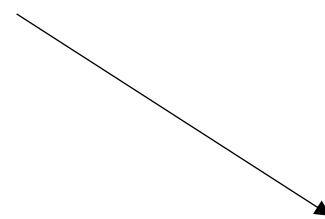
2DWMH

Fang (exp) shows best reattachment result
Dwight & Cherroud reattach too early

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2DWMH, at x/c=0.65

How new results stack up against standard SA model
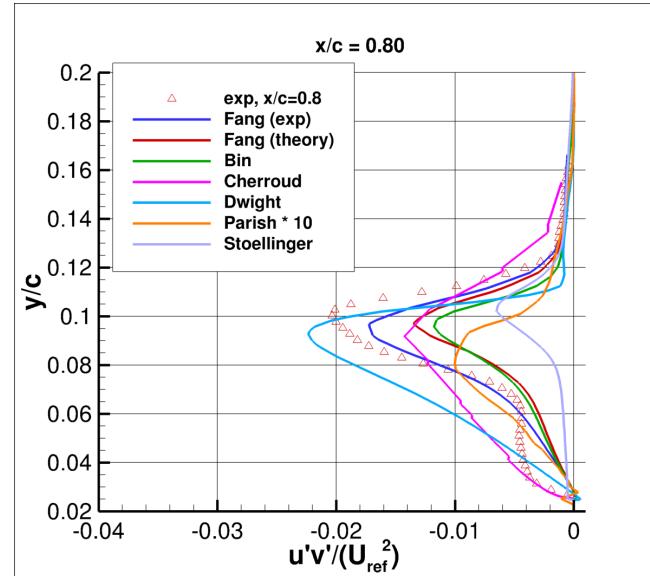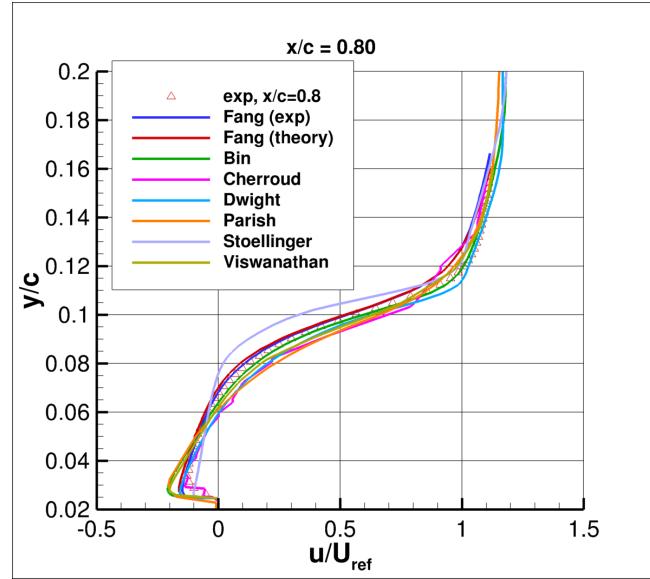
Cherroud and Stoellinger are furthest off in u'v'

2DWMH, at x/c=0.80

How new results stack up against standard SA model
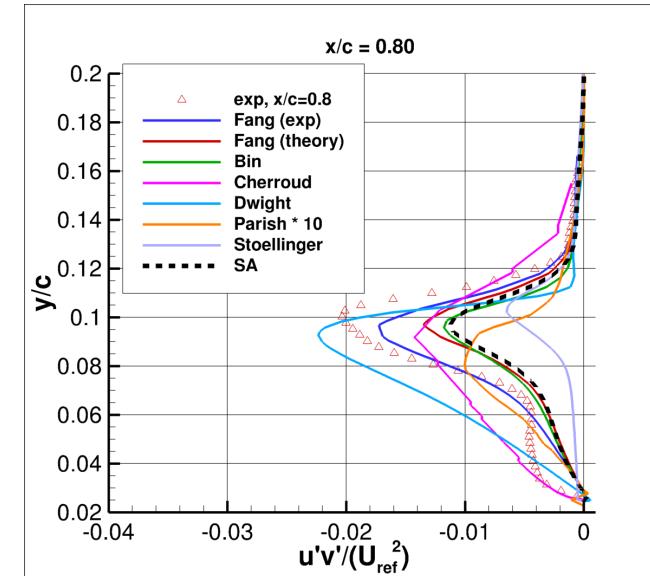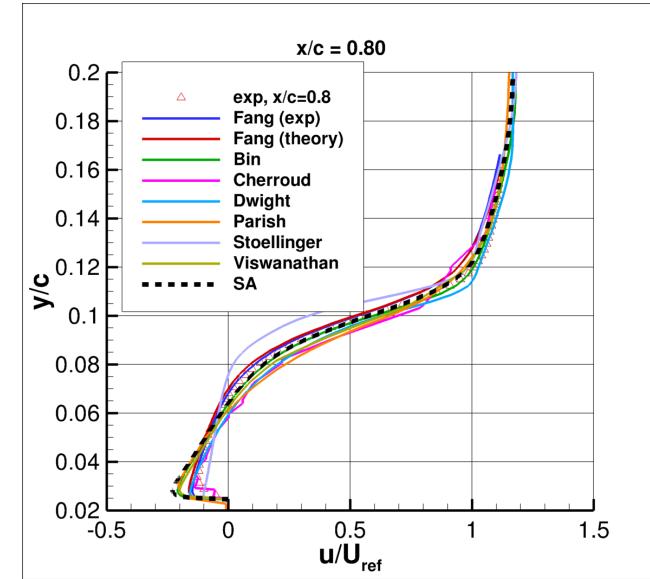
Stoellinger furthest from u profile

Fang (exp) and Dwight are closest to peak u'v'
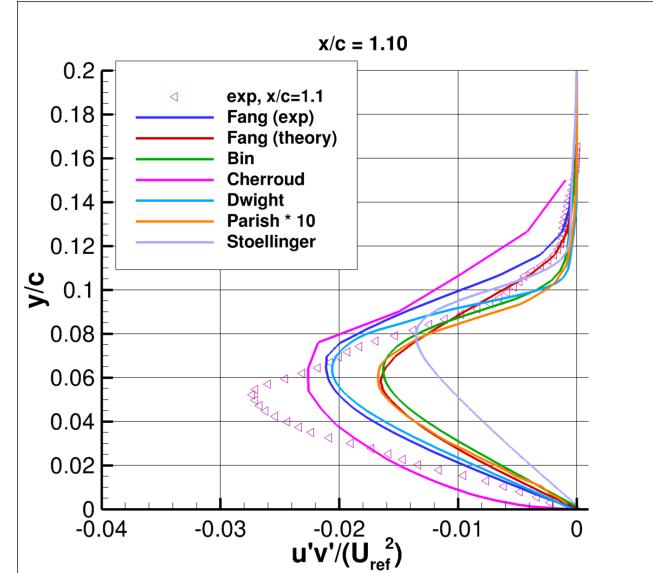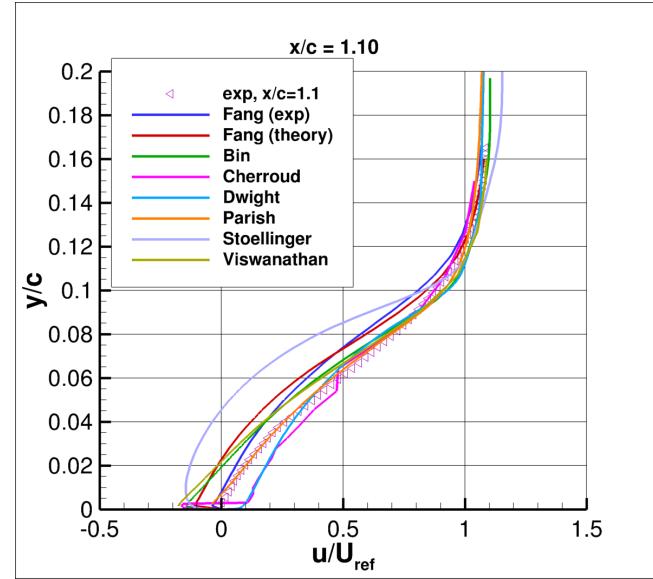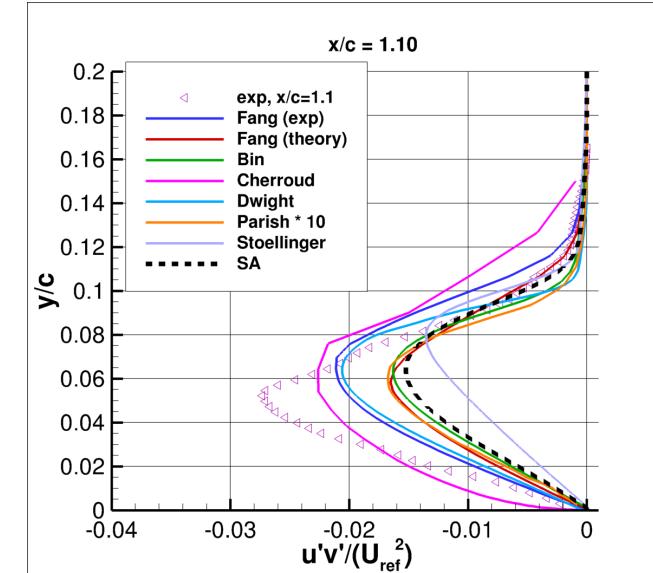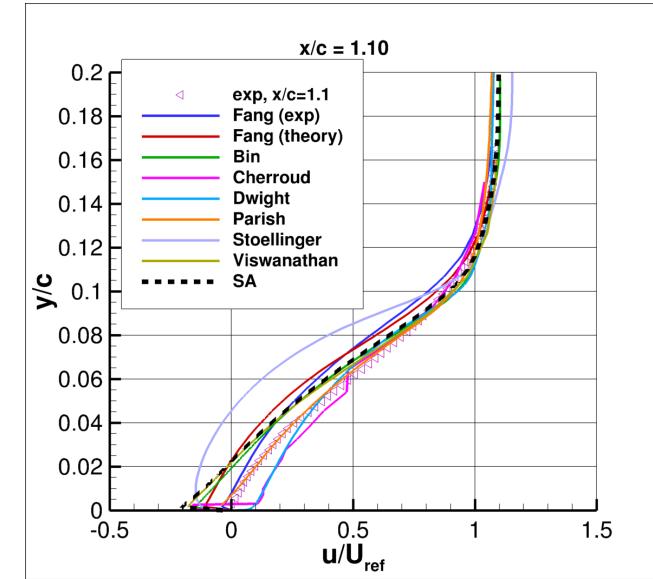
2DWMH, at x/c=1.10

Stoellinger furthest from u profile; Parish matches profile well

Fang (exp), Dwight, and Cherroud are closest to peak u'v'
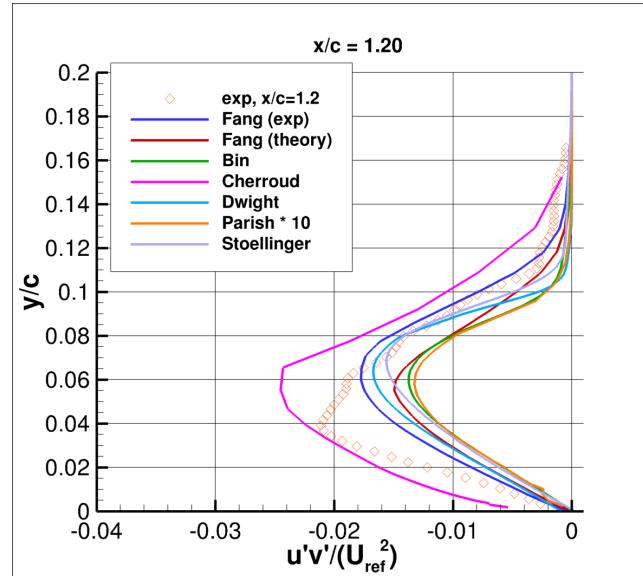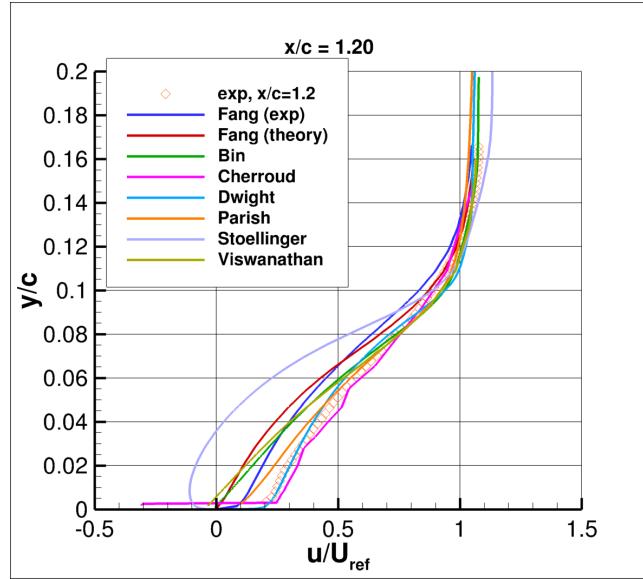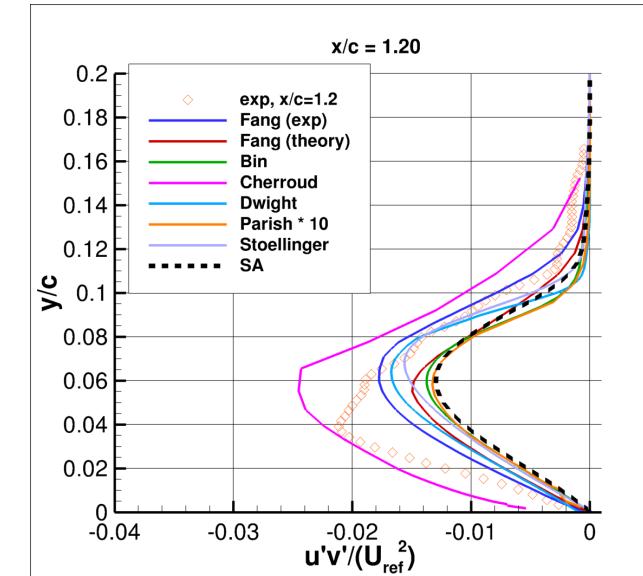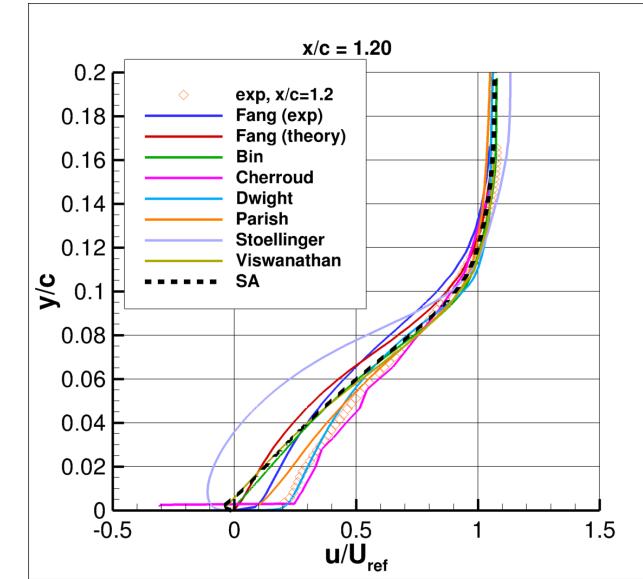
2DWMH, at x/c=1.20

Stoellinger furthest from u profile; Dwight and Cherroud (nonsmooth) match profile best
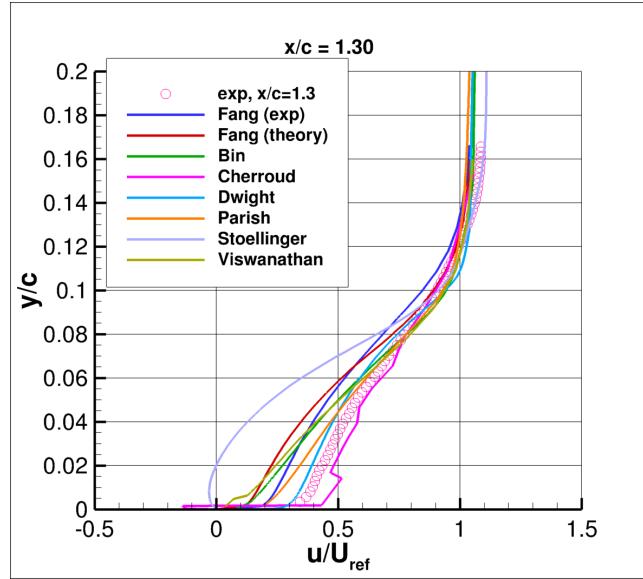
2DWMH, at x/c=1.30

How new results stack up against standard SA model
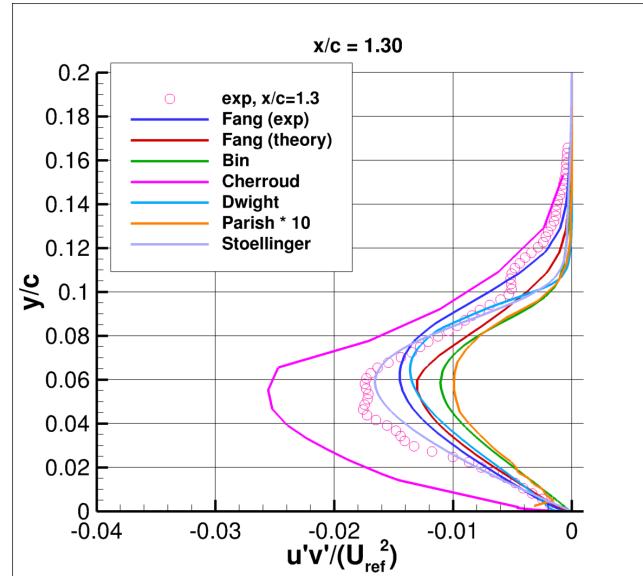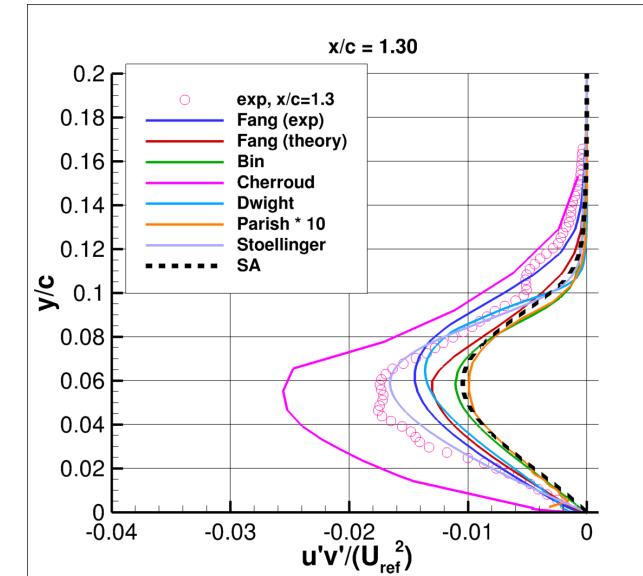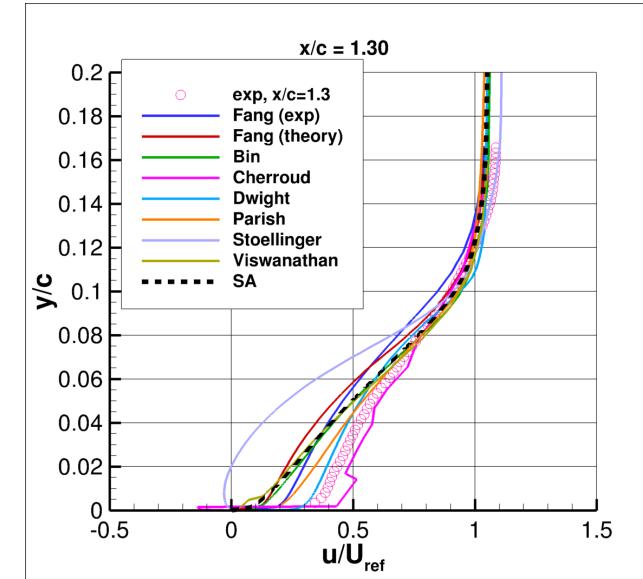
Stoellinger furthest from
u profile; Dwight and
Cherroud (nonsmooth)
match profile best

Stoellinger matches
u'v' peak best
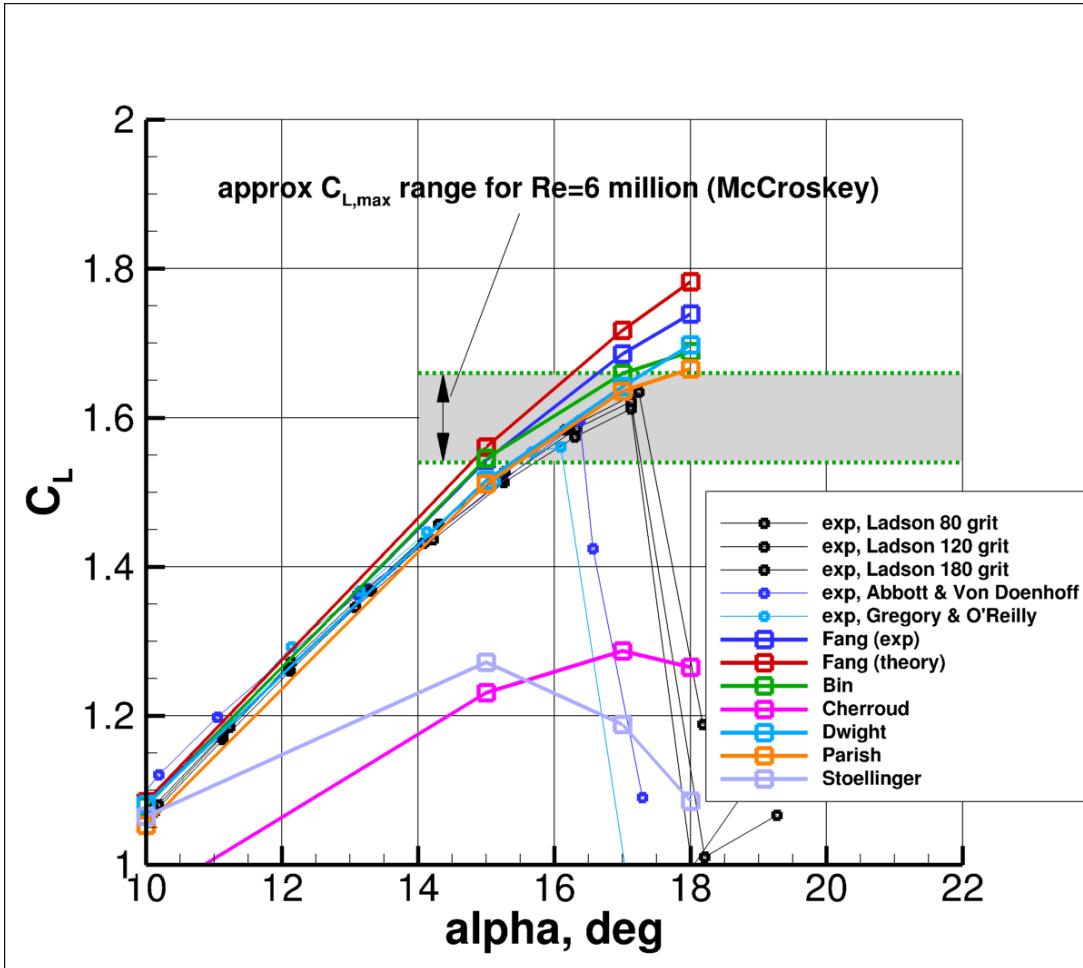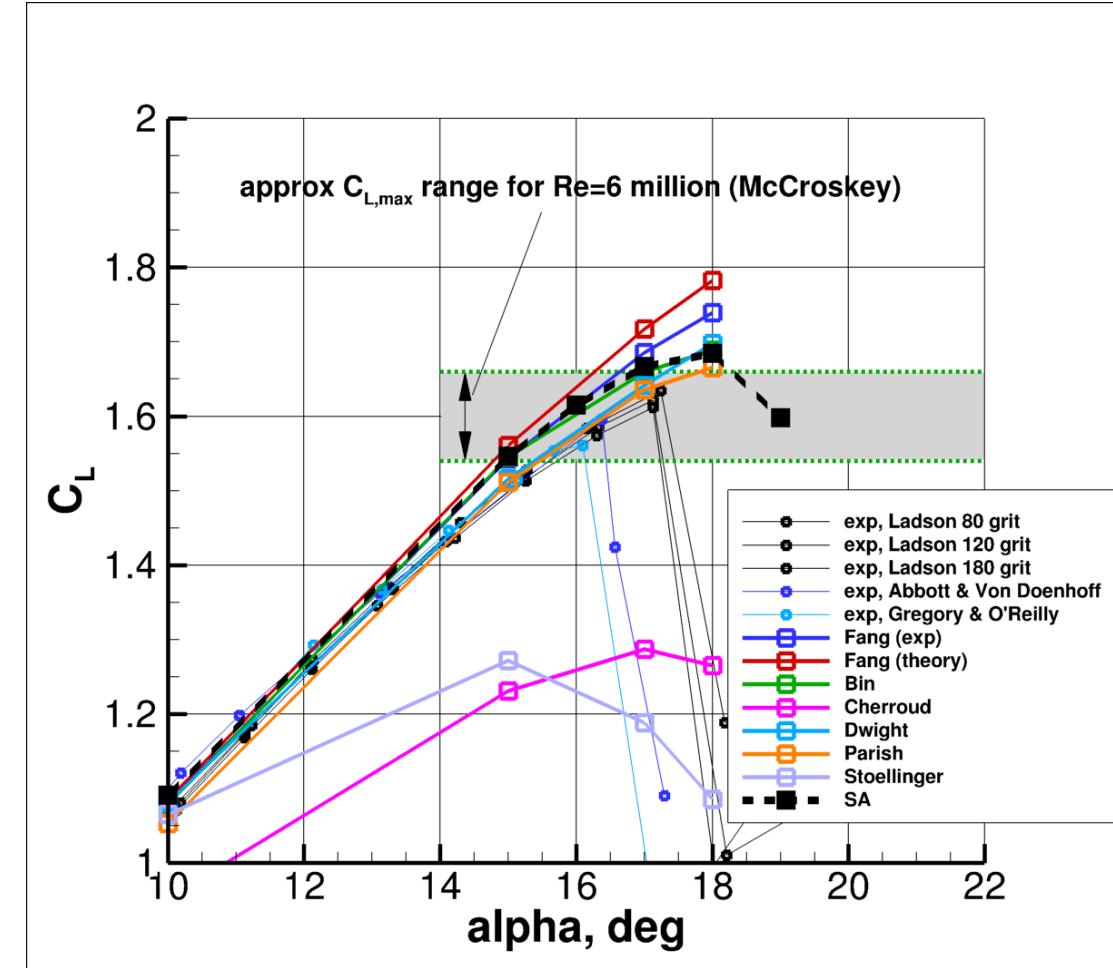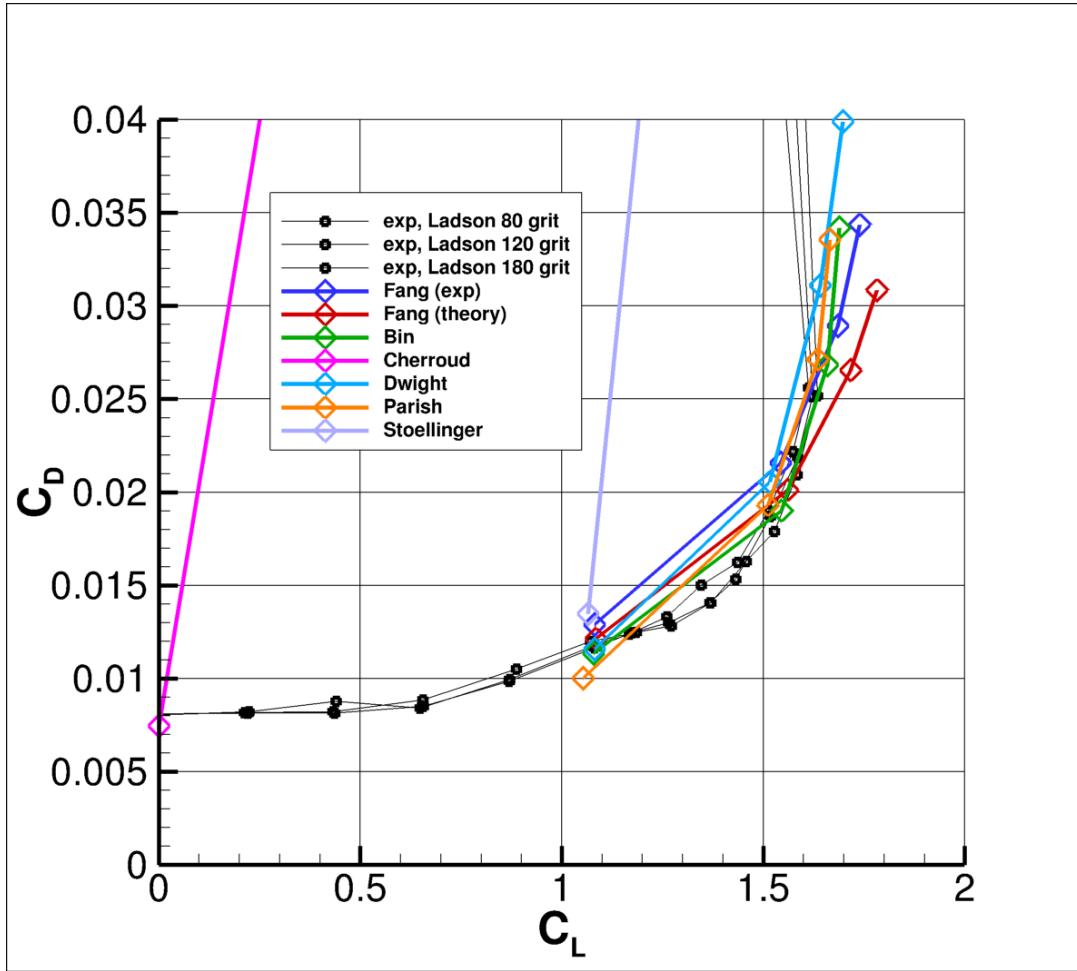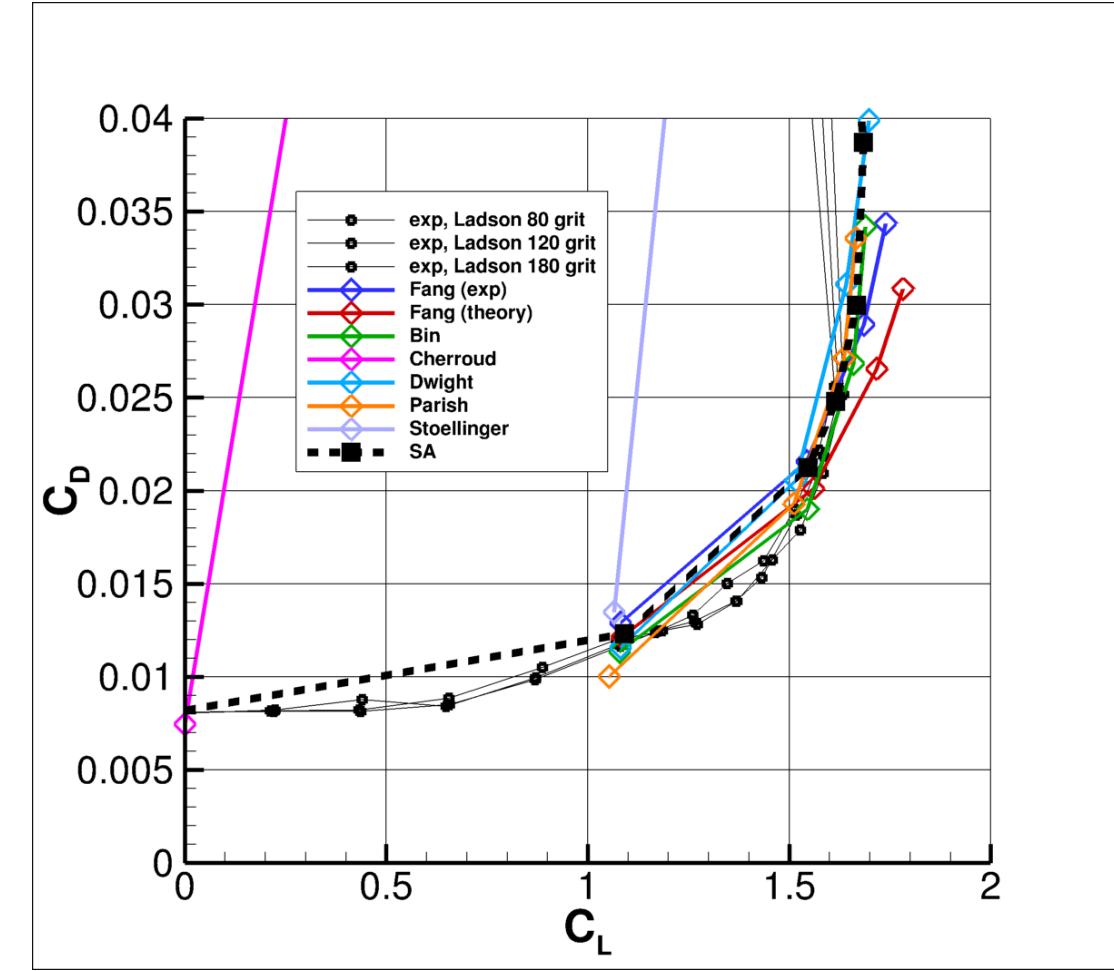
2DN00

Stoellinger and Cherroud give very low CL

2DN00
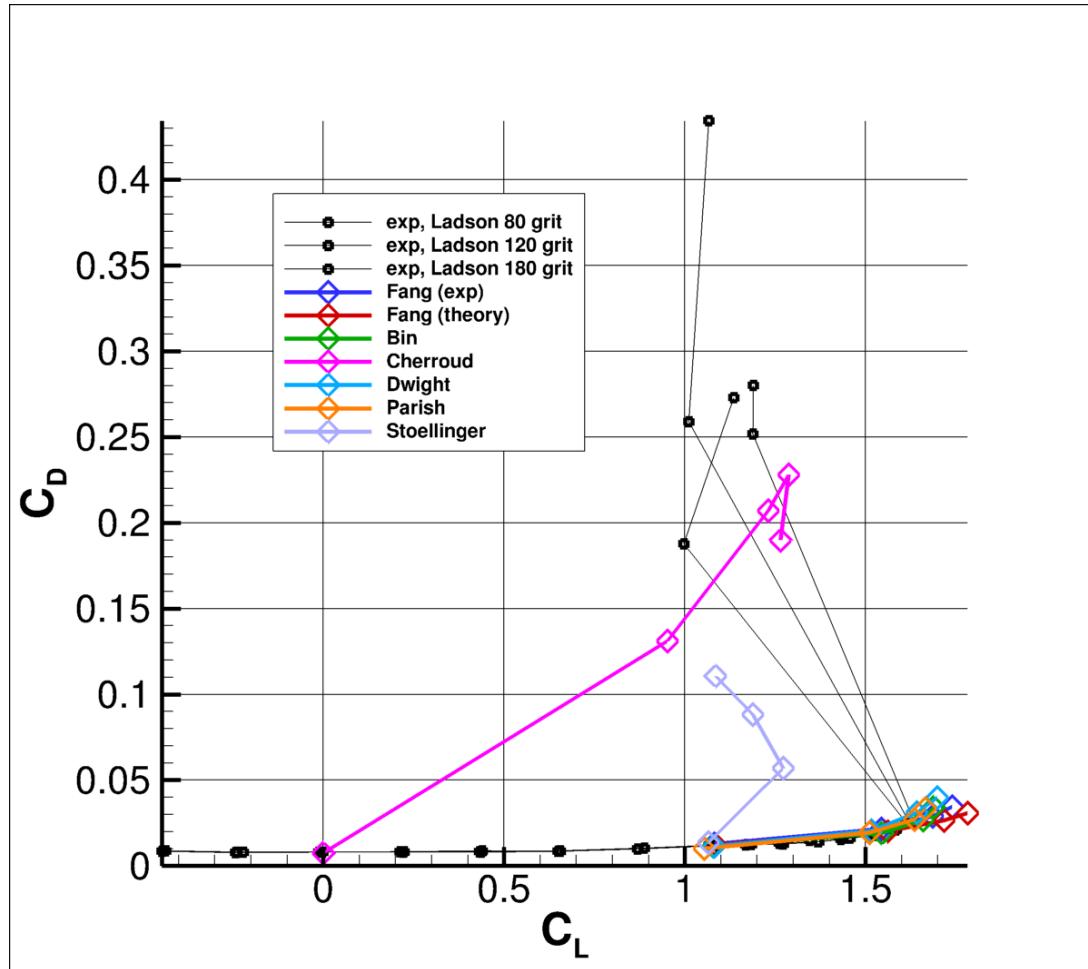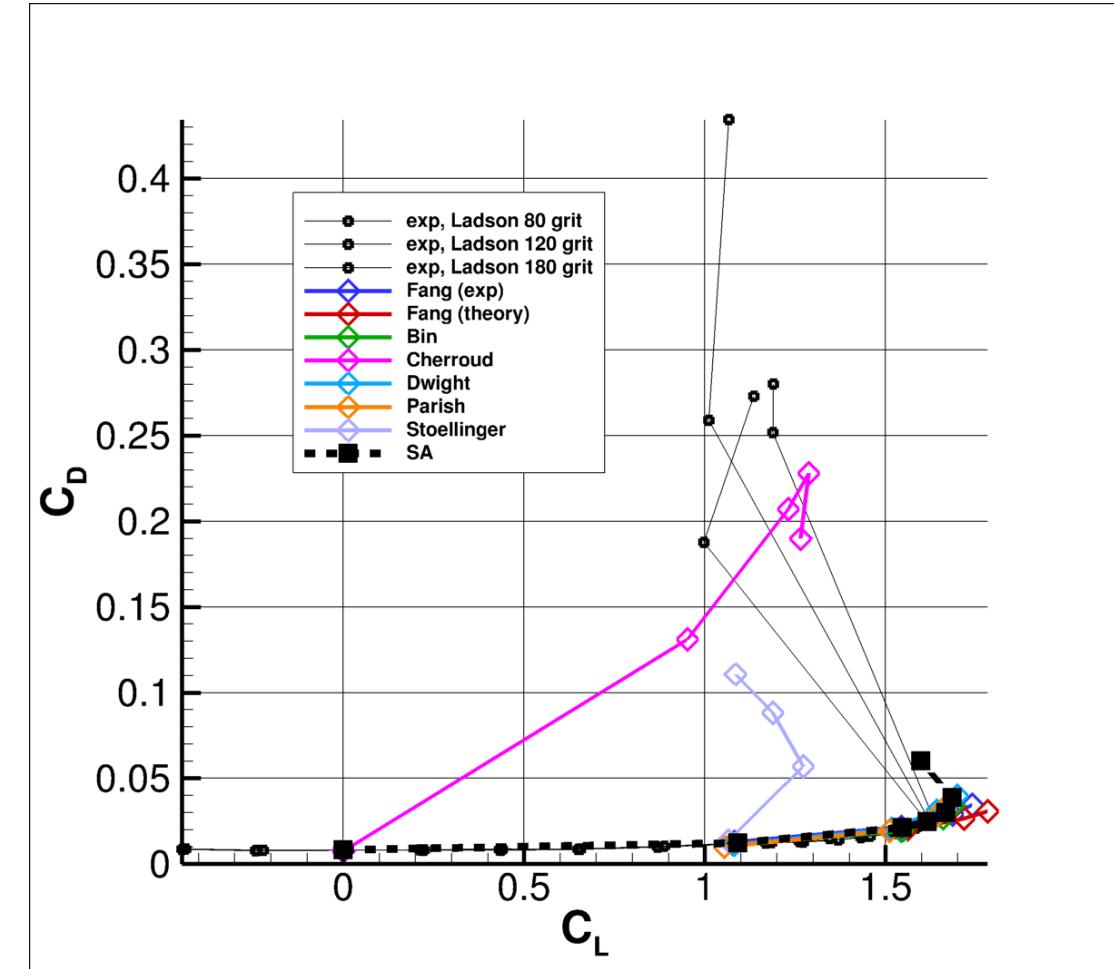
Stoellinger and Cherroud give very high CD
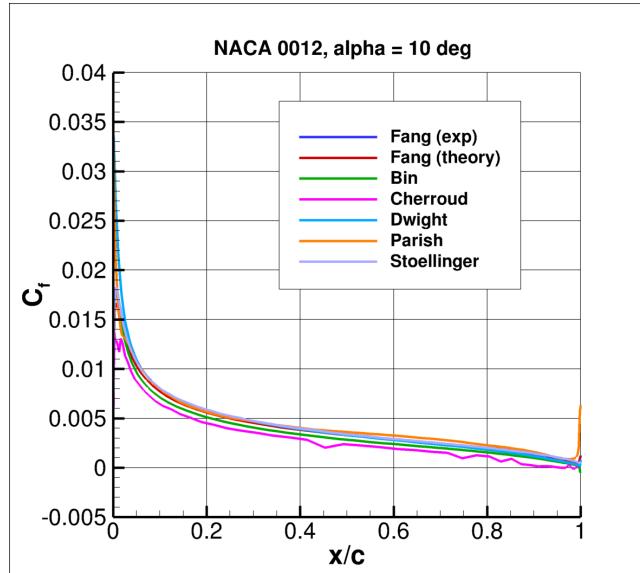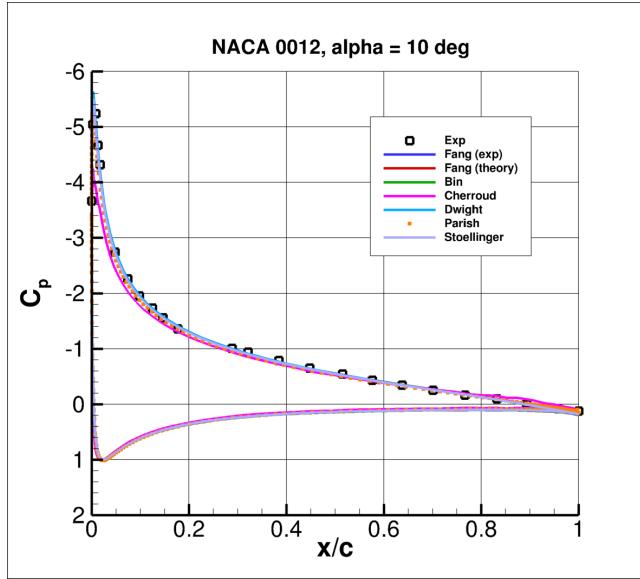
2DN00

Stoellinger and Cherroud give very high CD
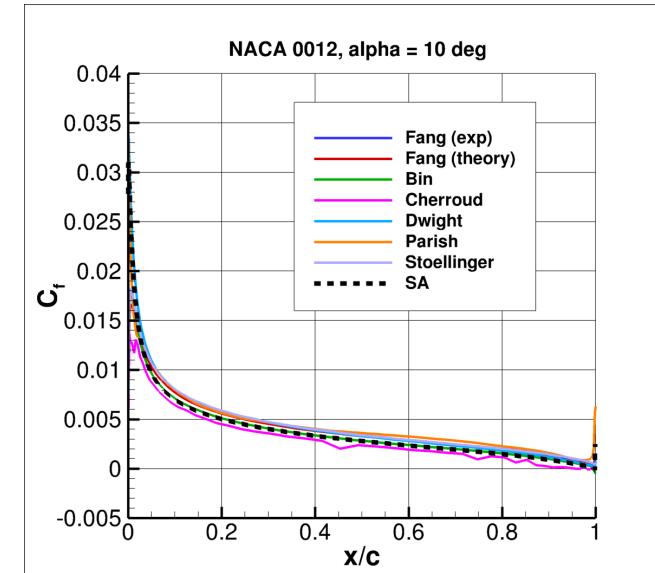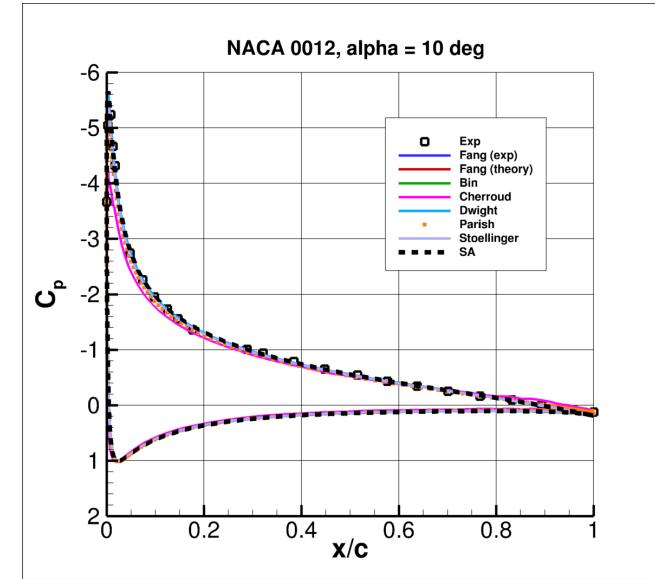
2DN00, AoA=10 deg.

How new results stack up against standard SA model

All fairly reasonably; Cherroud has lower peak Cp
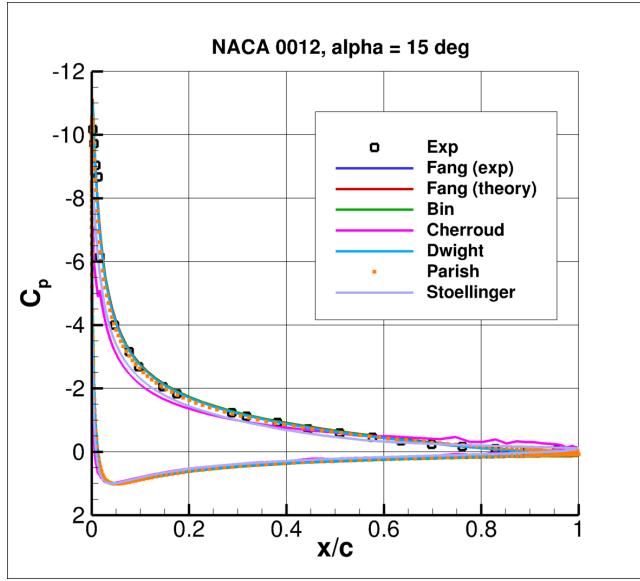
Cherroud results are nonsmooth
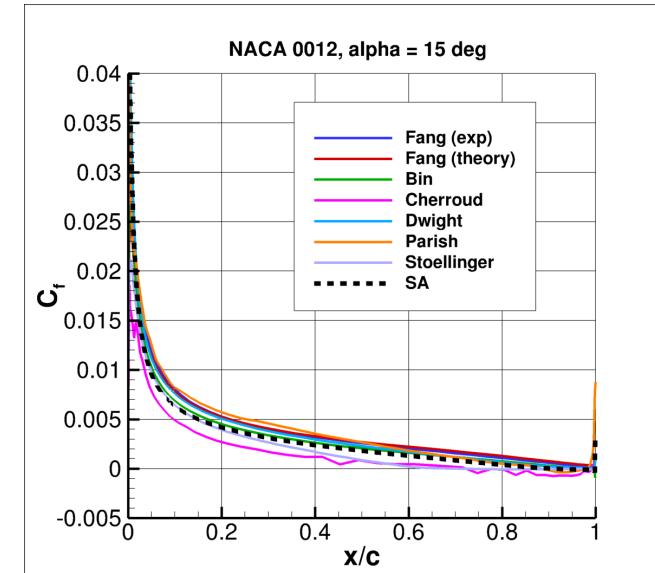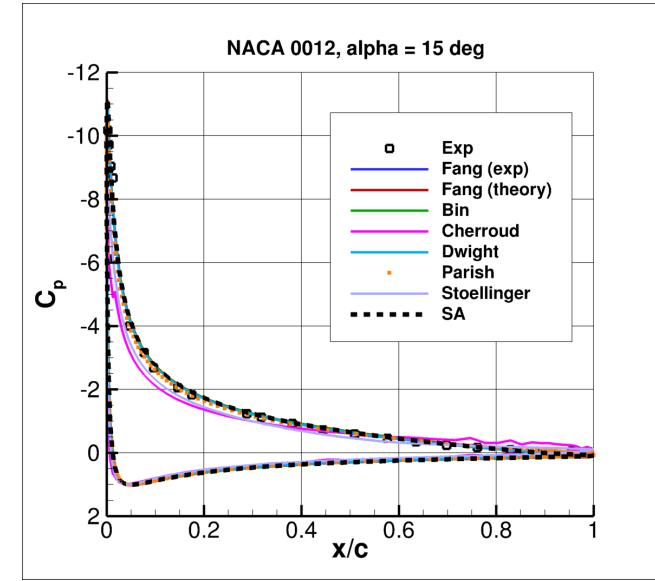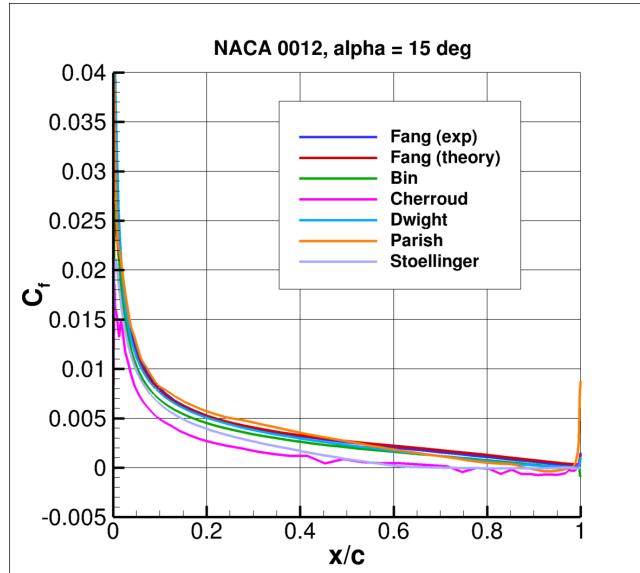
2DN00, AoA=15 deg.

How new results stack up against standard SA model

All fairly reasonably; Cherroud and Stoellinger have lower peak Cp
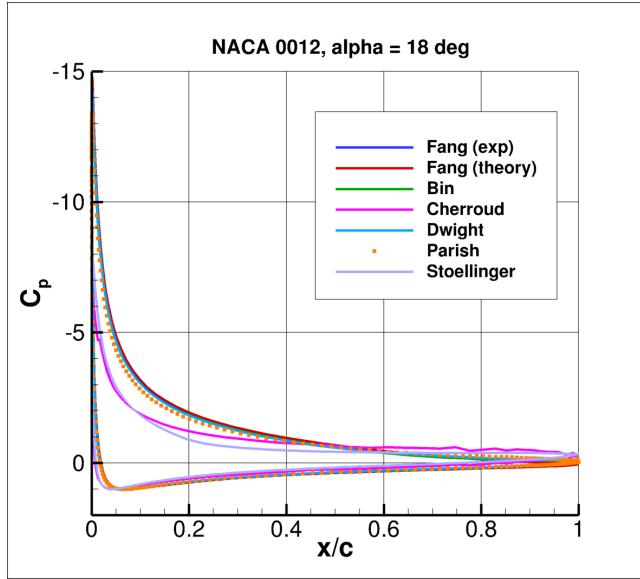
Cherroud results are nonsmooth; Cherroud and Stoellinger separate earlier than others
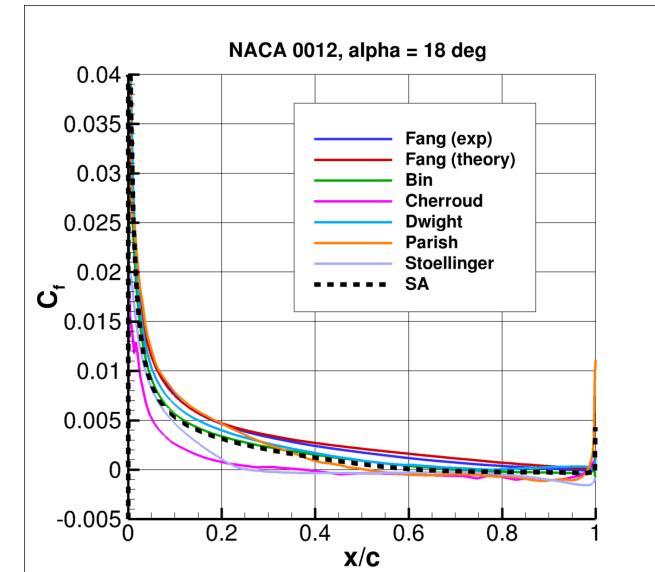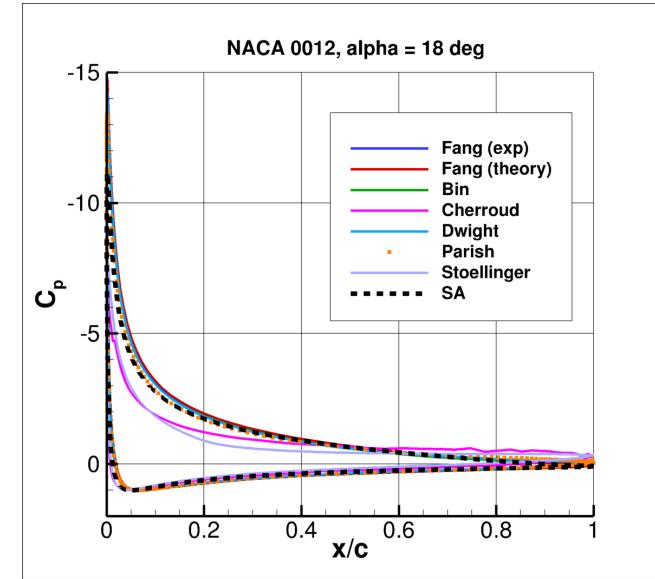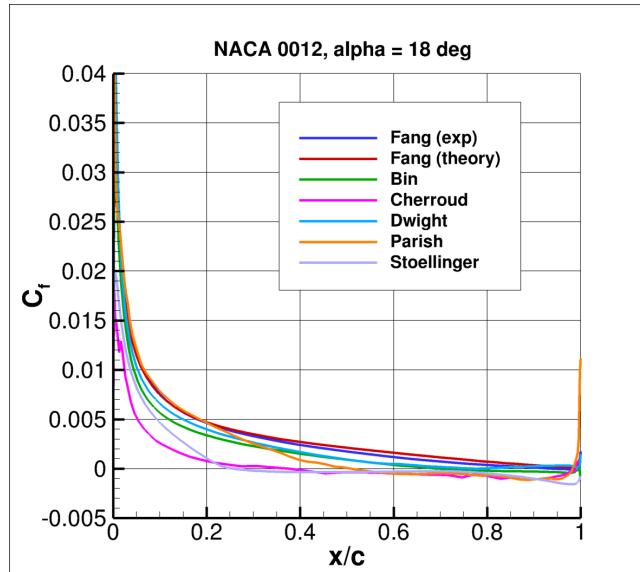
2DN00, AoA=18 deg.

How new results stack up against standard SA model

Cherroud and Stoellinger have lower peak Cp
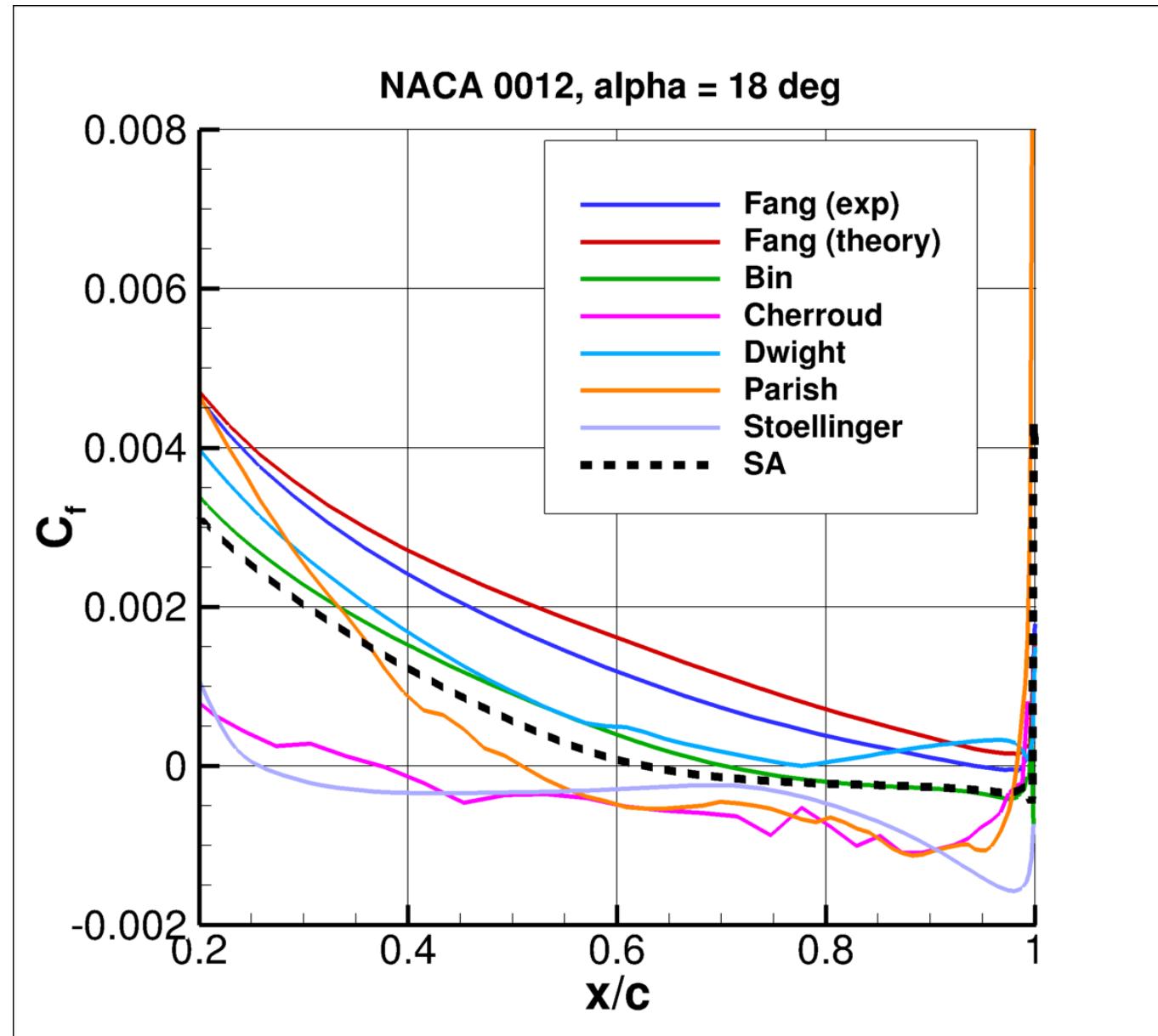
Cherroud results are nonsmooth;
Cherroud, Stoellinger, and Parish separate earlier than others

2DN00, AoA=18 deg.

Participant results vary from upper surface separation at x/c=0.25 through fully attached!

NACA 0012, alpha = 18 deg

Bottom Line

- The fact that the participants were able to use a "single strategy" to yield plausible results for so many diverse cases was a positive outcome

- However, despite isolated successes, it appears to be very difficult to achieve broad agreement across multiple diverse cases with a single RANS model

- Possibly carry these cases forward for future (continuing) challenge(s)