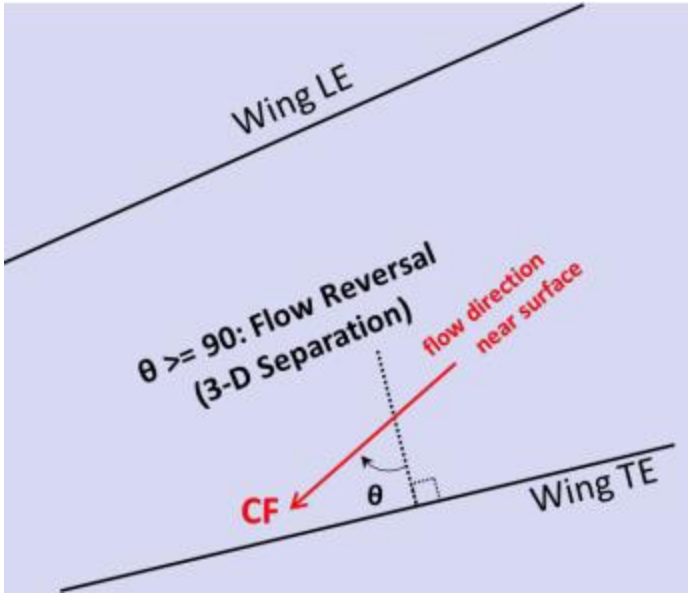
Trailing Edge Separation

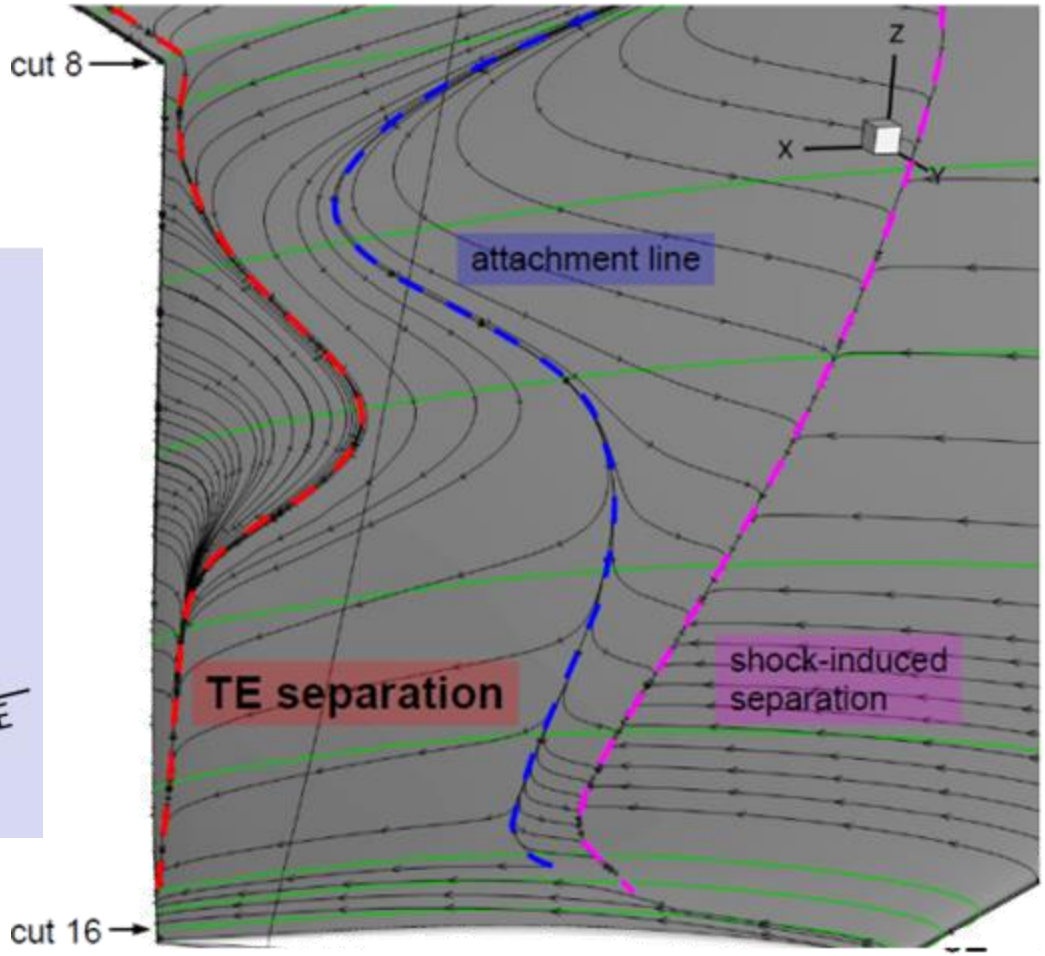
- **Trailing Edge Separation**
  - **17 Submitted Data Sets (*as of June 24*)**

Grids	Turbulence Models
11 Unstructured	3 SA (RC)
3 Overset	10 SA QCR (RC)
2 Multi-block	1 AMM QCR
1 Hybrid Unstr/Cart	1 SST
	2 EARSM

Trailing Edge Separation

- Criteria: C_f normal to TE < 0
  - difficult to detect at higher α

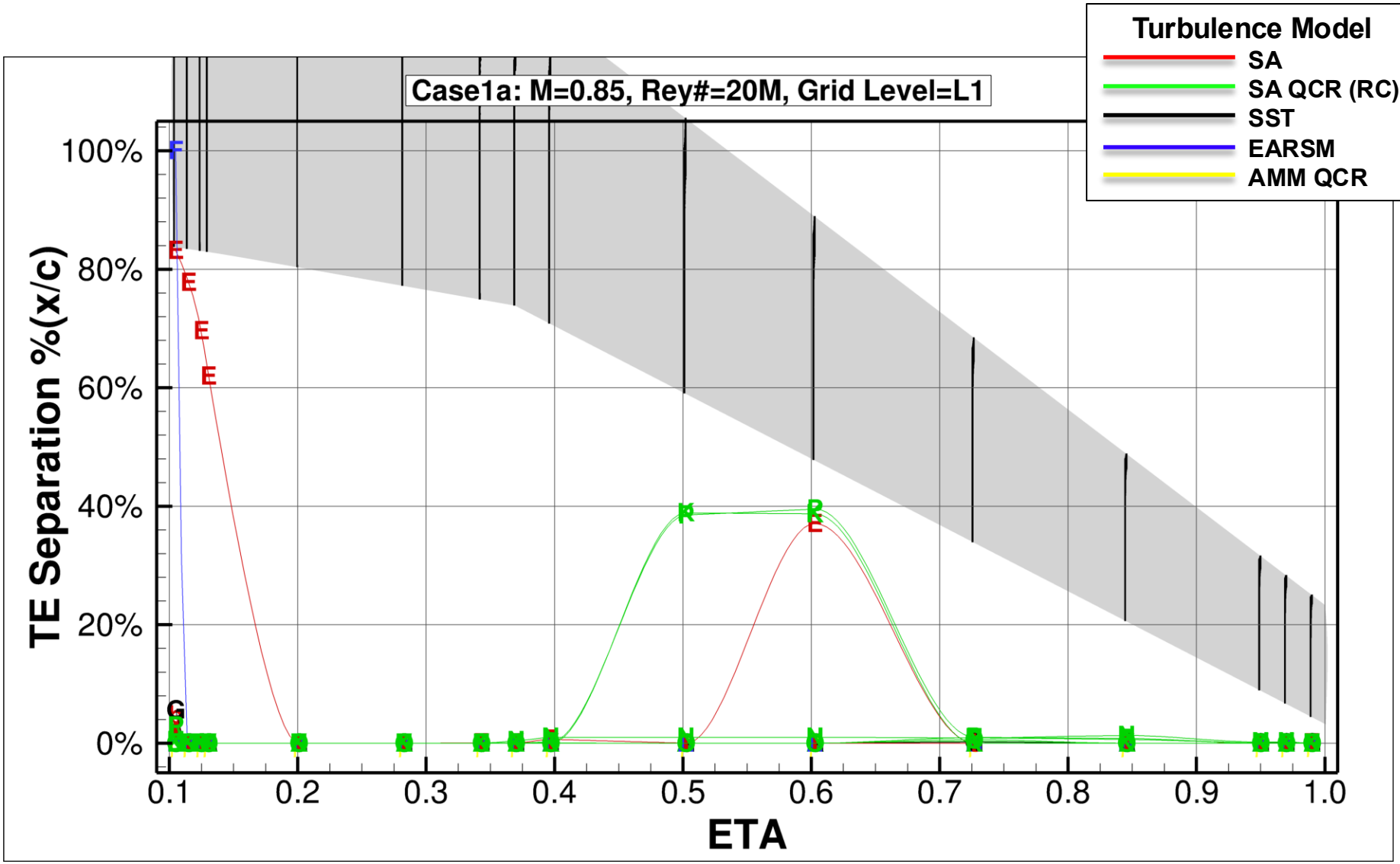


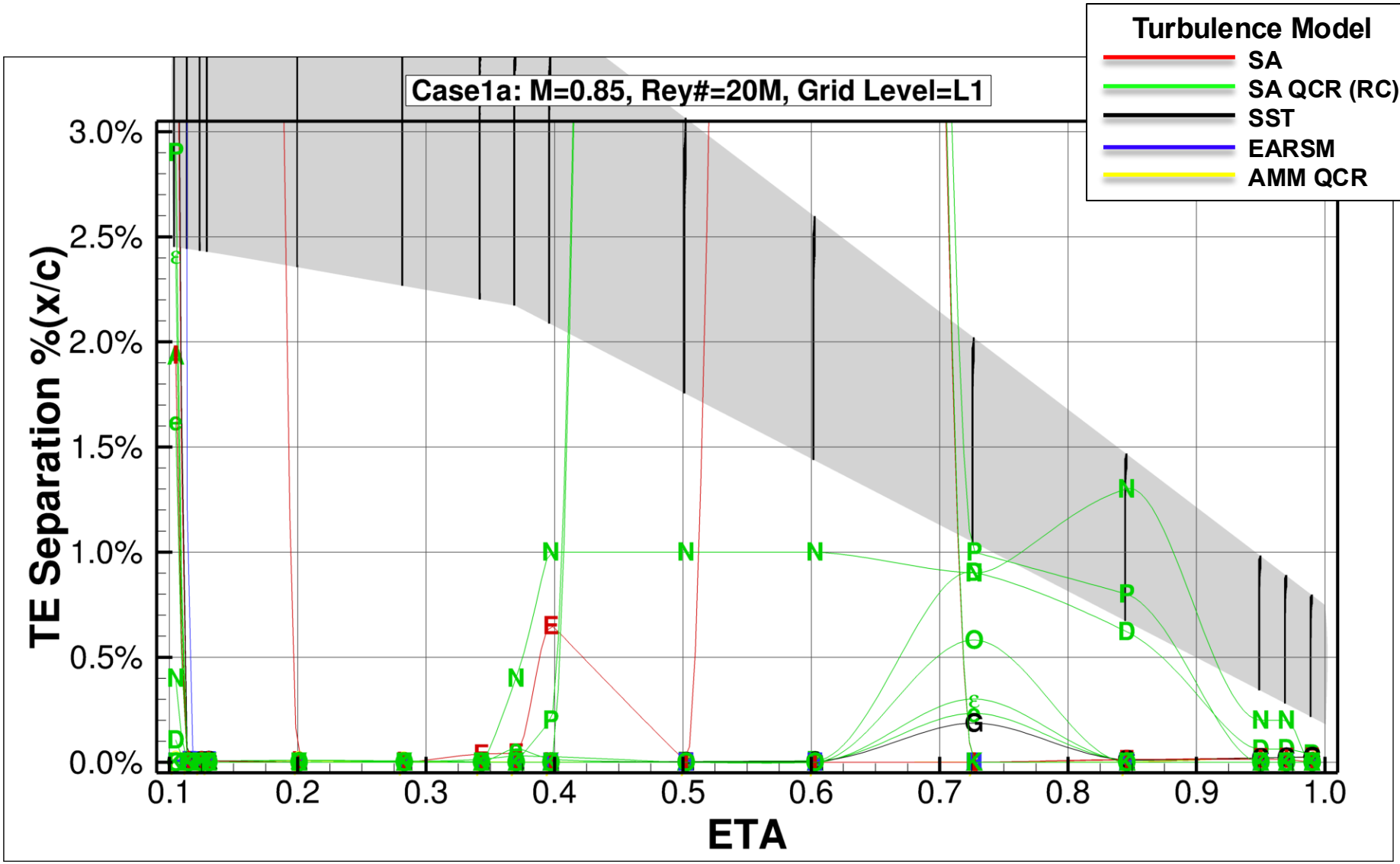


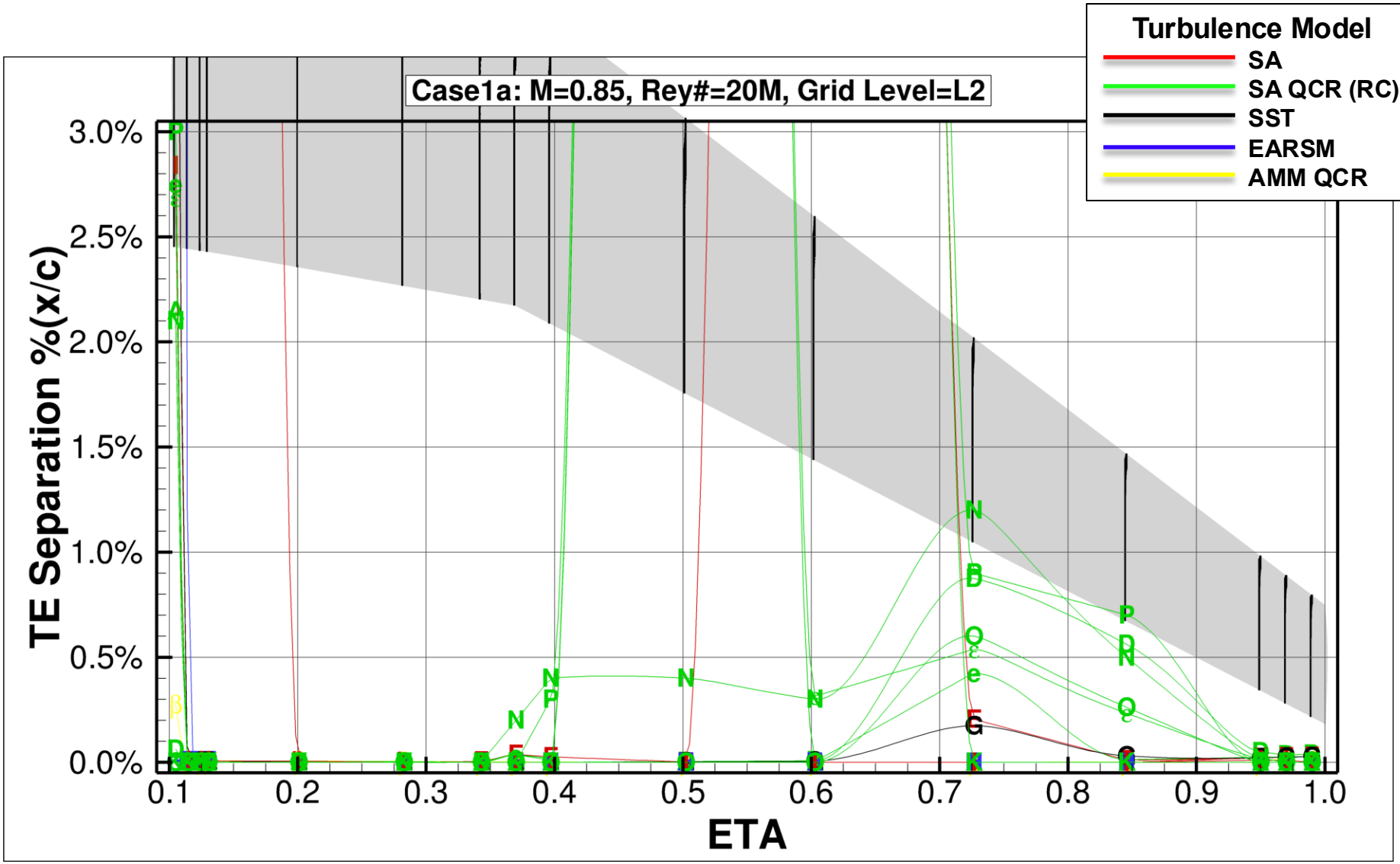
Case 1a

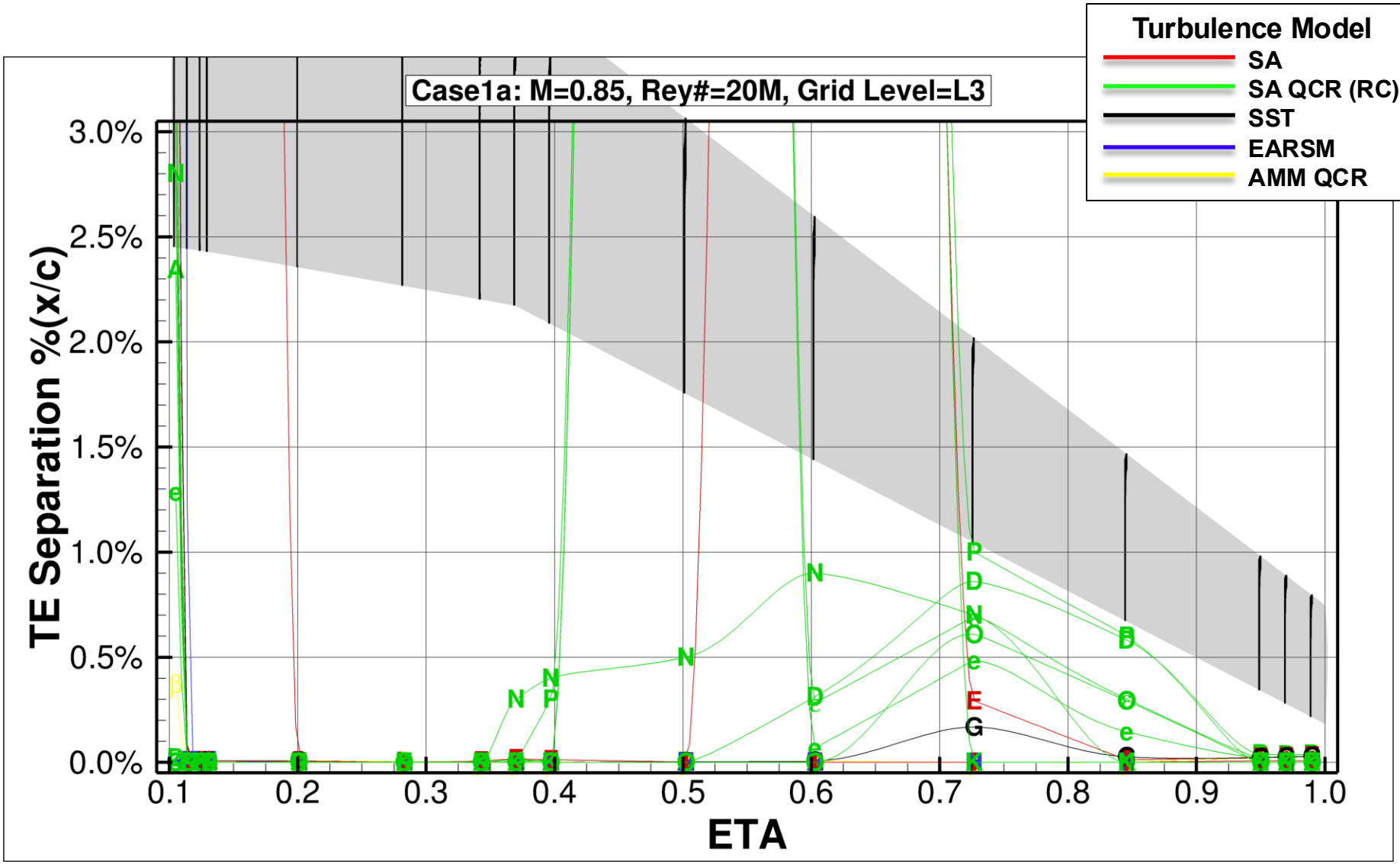
CRM Wing-Body Grid Convergence Study

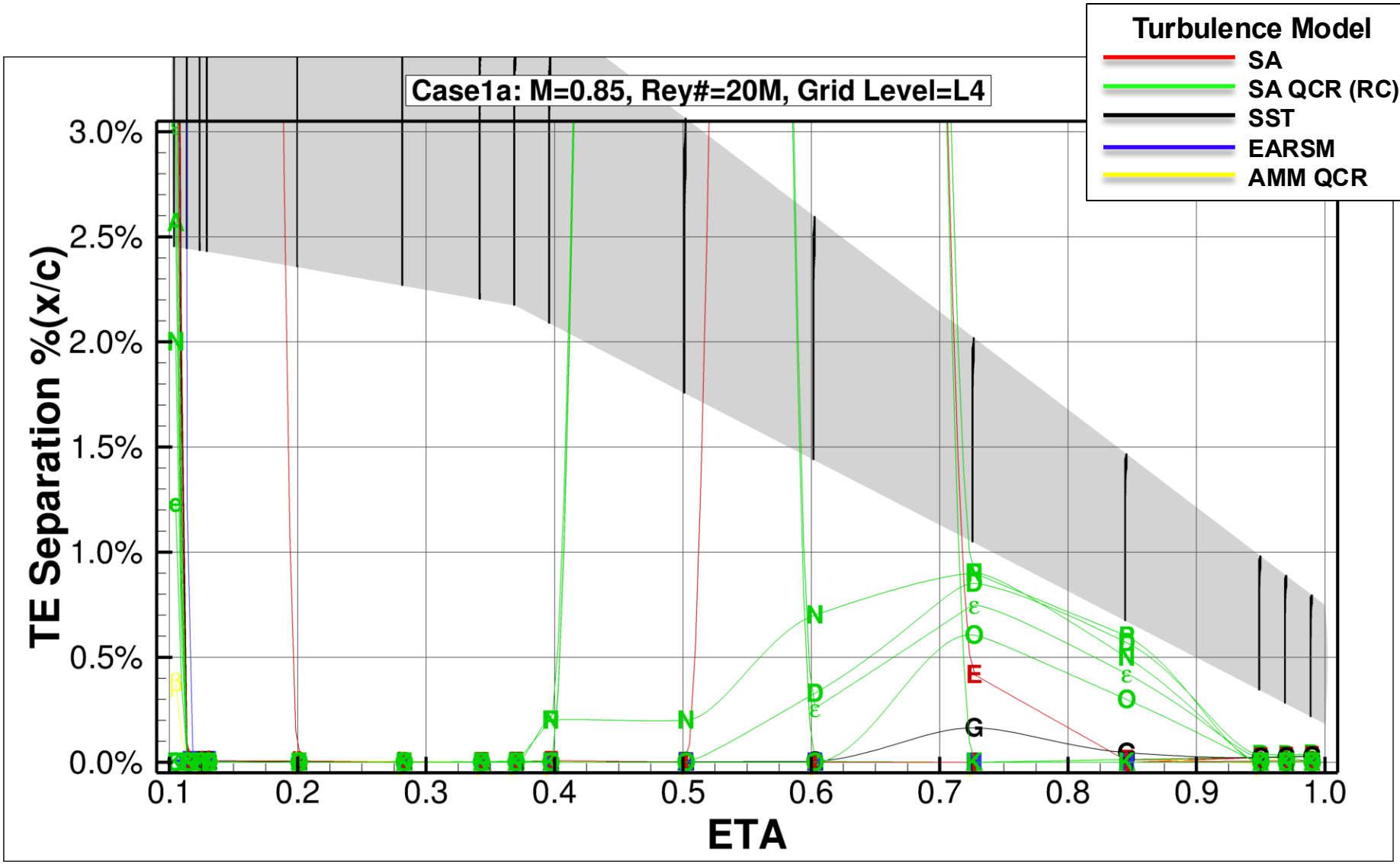
M = 0.85 |C_L = 0.58 |Rey# = 20M

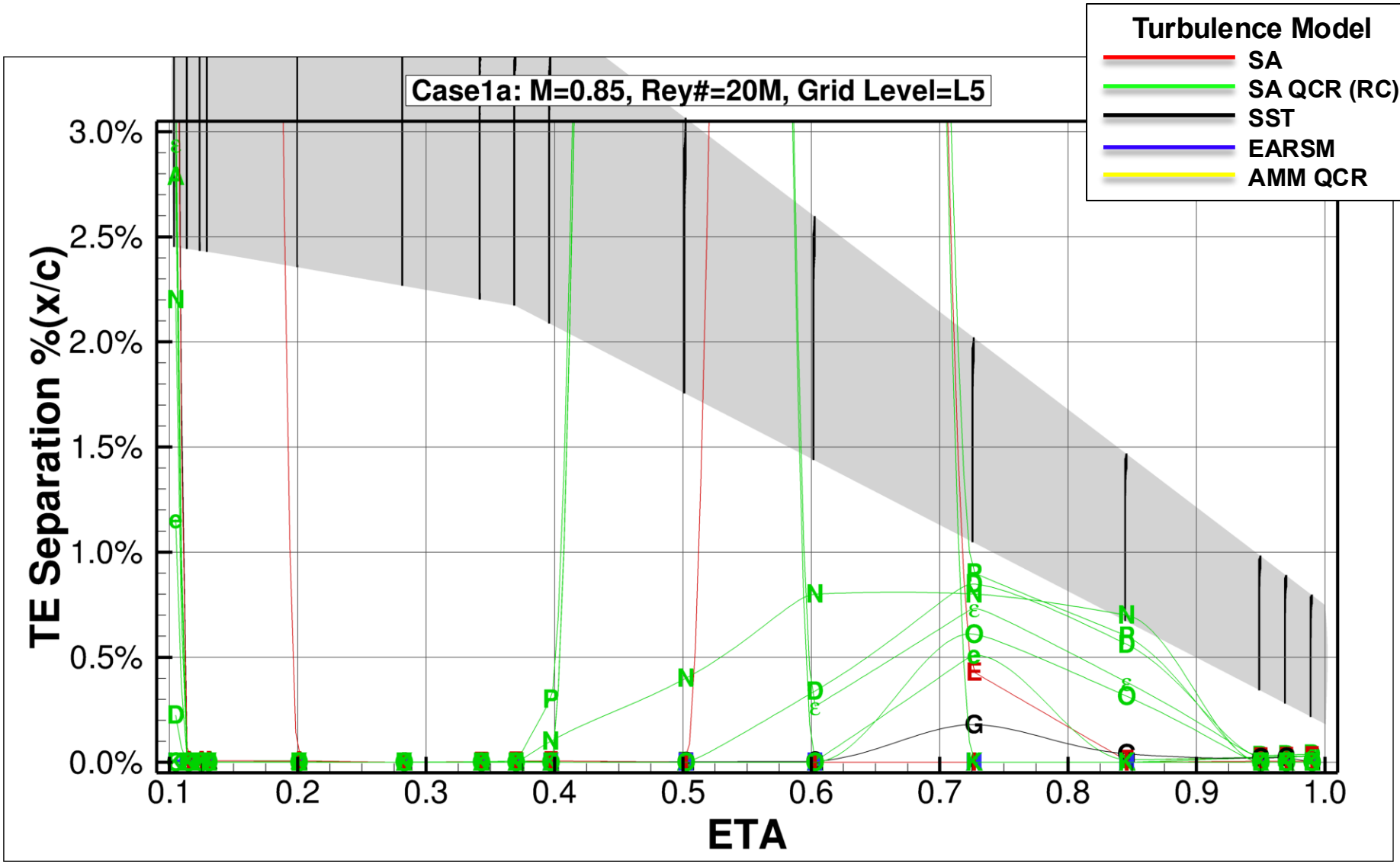

Case1a: M=0.85, Rey#=20M, Grid Level=L1
Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
TE Separation %(x/c)
100%
80%
60%
40%
20%
0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA

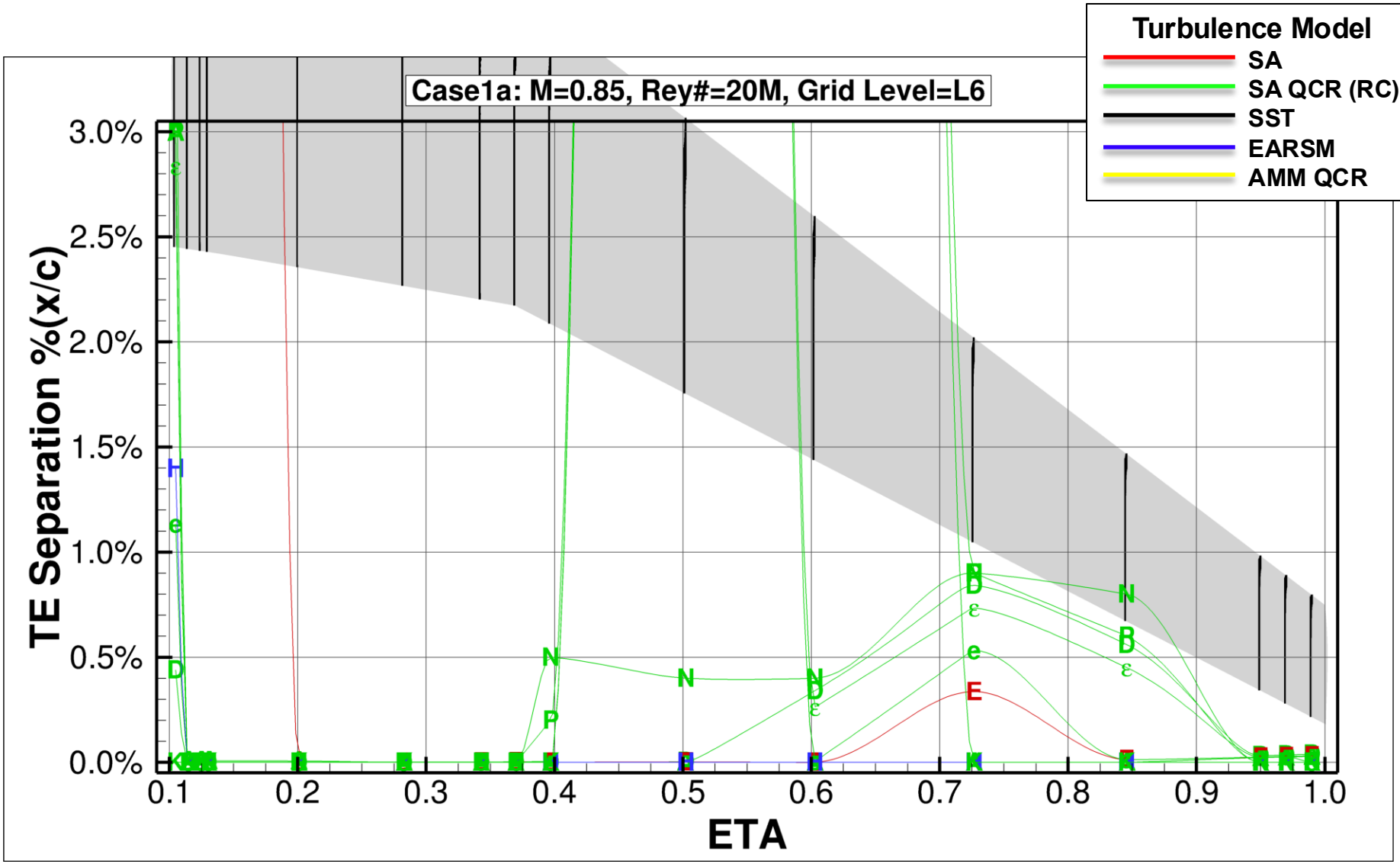

Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
Case1a: M=0.85, Rey#=20M, Grid Level=L1
TE Separation %(x/c)
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA


Case1a: M=0.85, Rey#=20M, Grid Level=L2
Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
TE Separation %(x/c)
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA

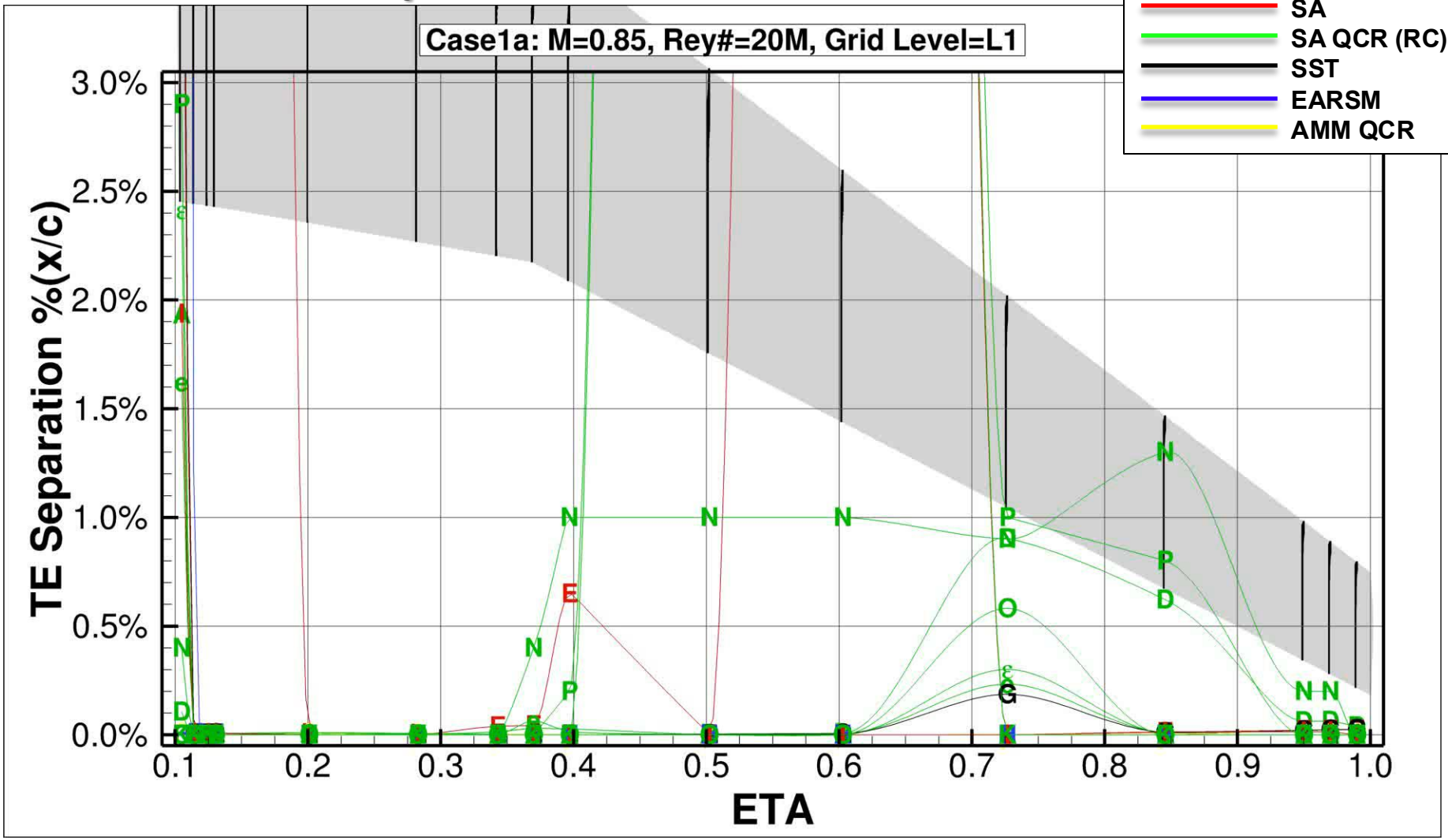

Case1a: M=0.85, Rey#=20M, Grid Level=L3
Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
TE Separation %(x/c)
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA


Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
Case1a: M=0.85, Rey#=20M, Grid Level=L4
TE Separation %(x/c)
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA


Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
Case1a: M=0.85, Rey#=20M, Grid Level=L5
TE Separation %(x/c)
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA


Case1a: M=0.85, Rey#=20M, Grid Level=L6
Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
TE Separation %(x/c)
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA

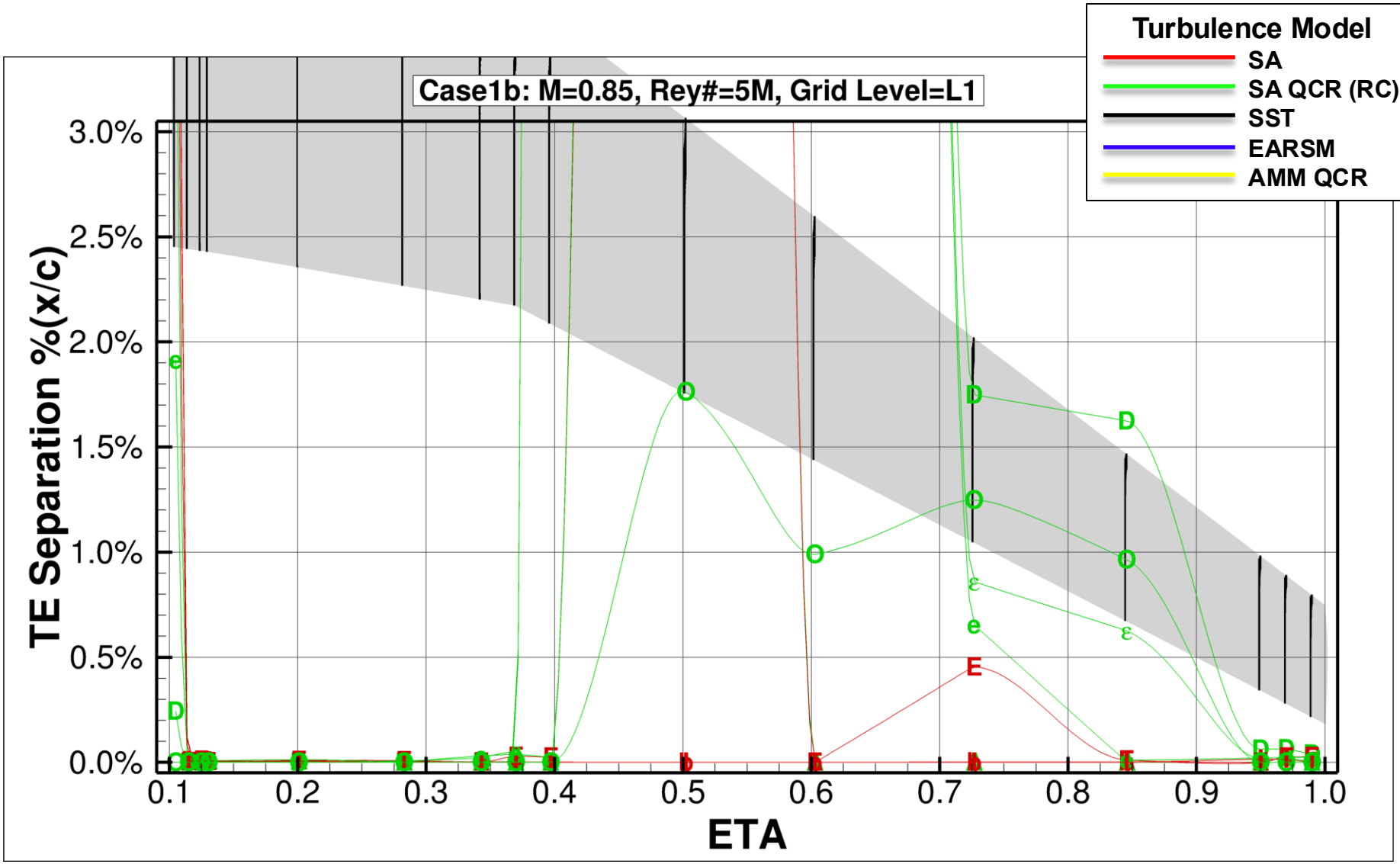
Animated Sweep

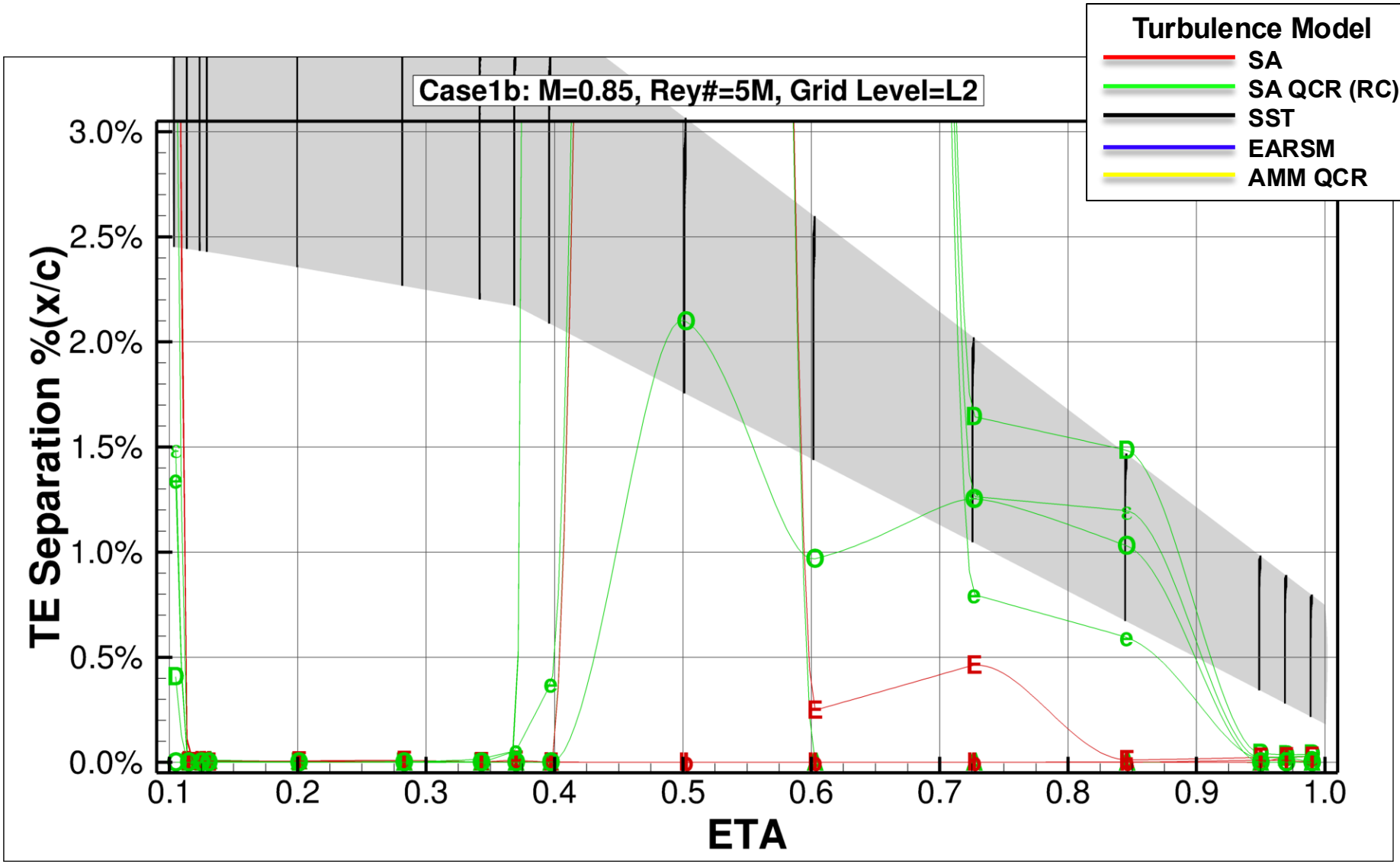


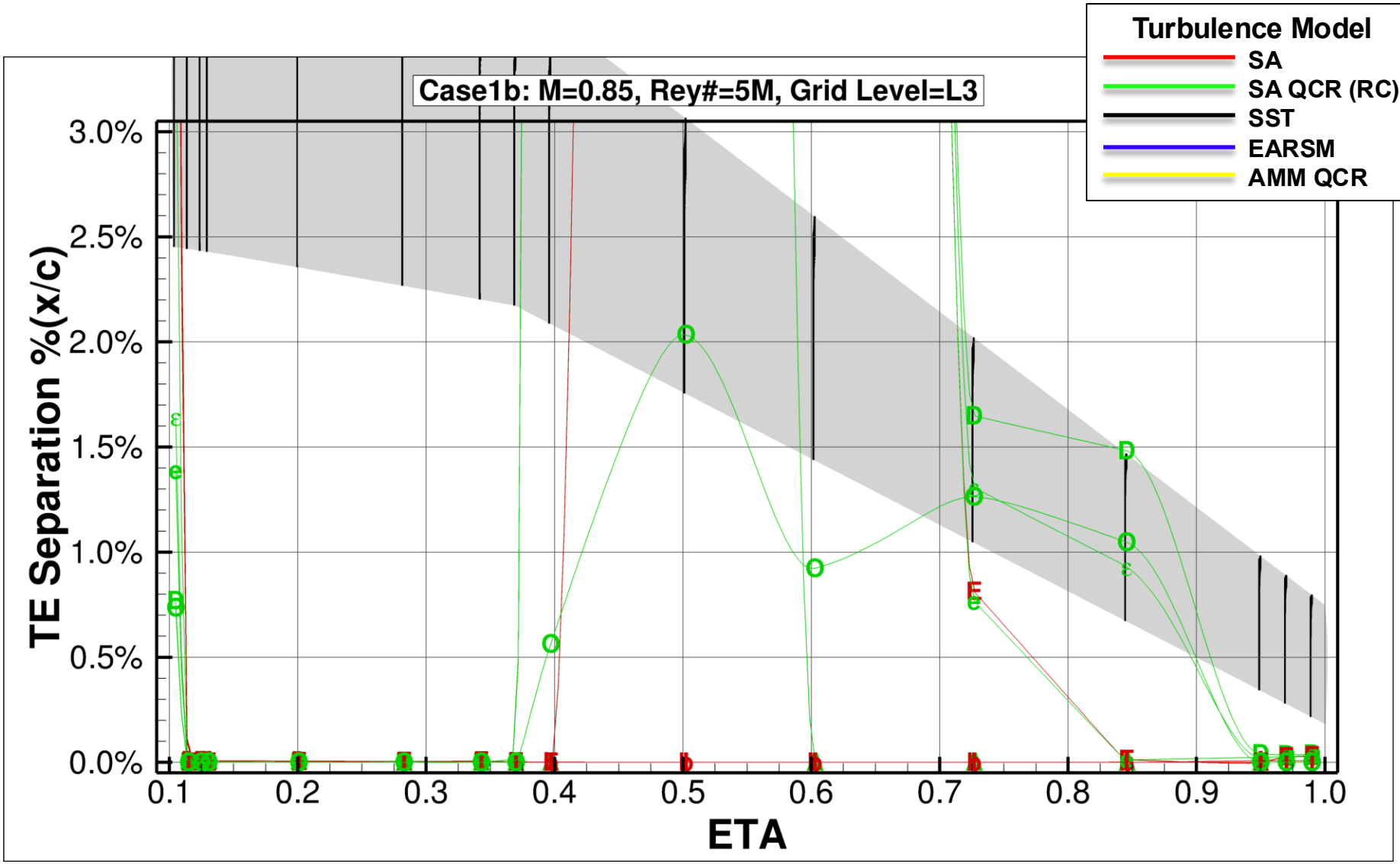
Case 1b

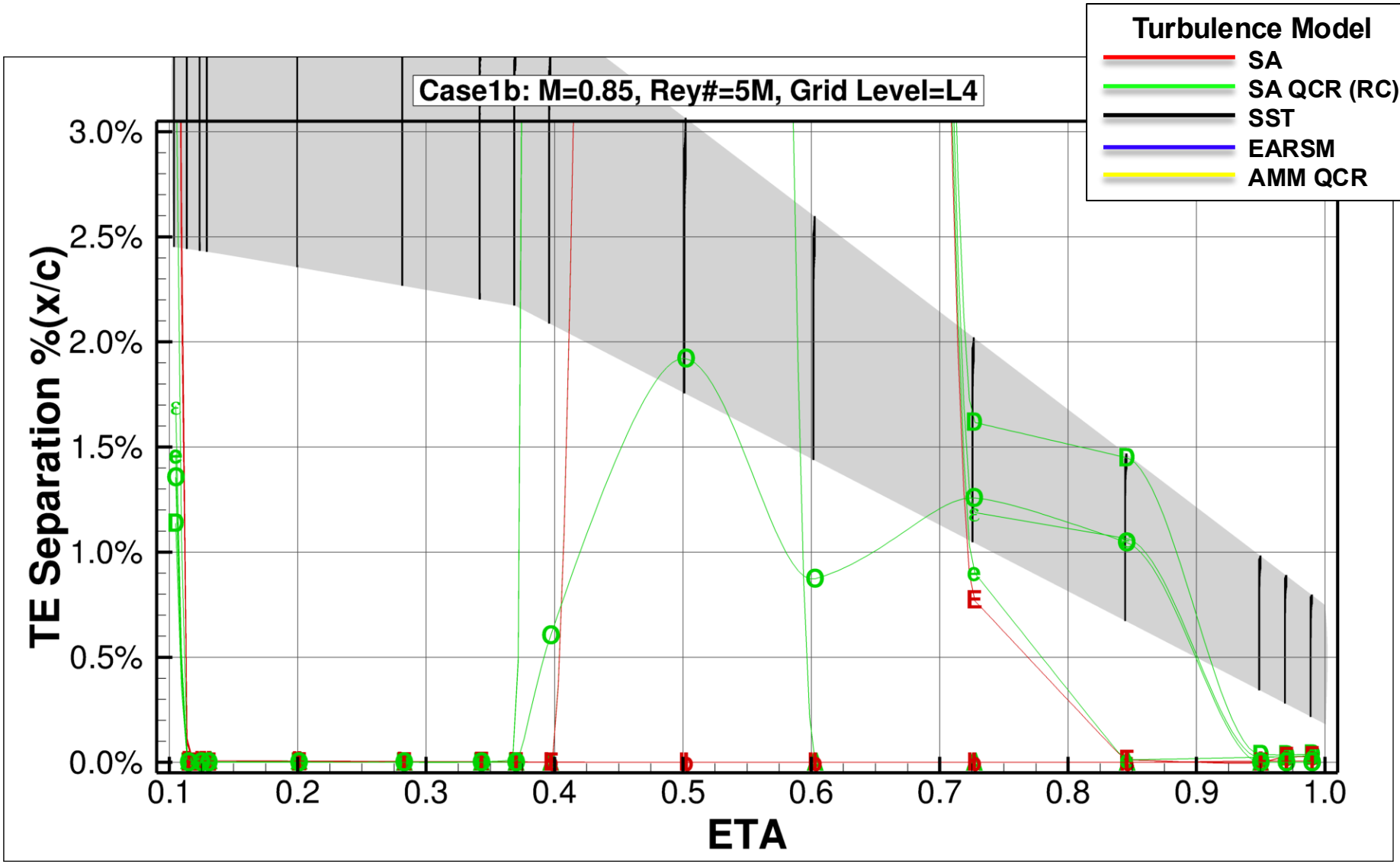
CRM Wing-Body Grid Convergence Study

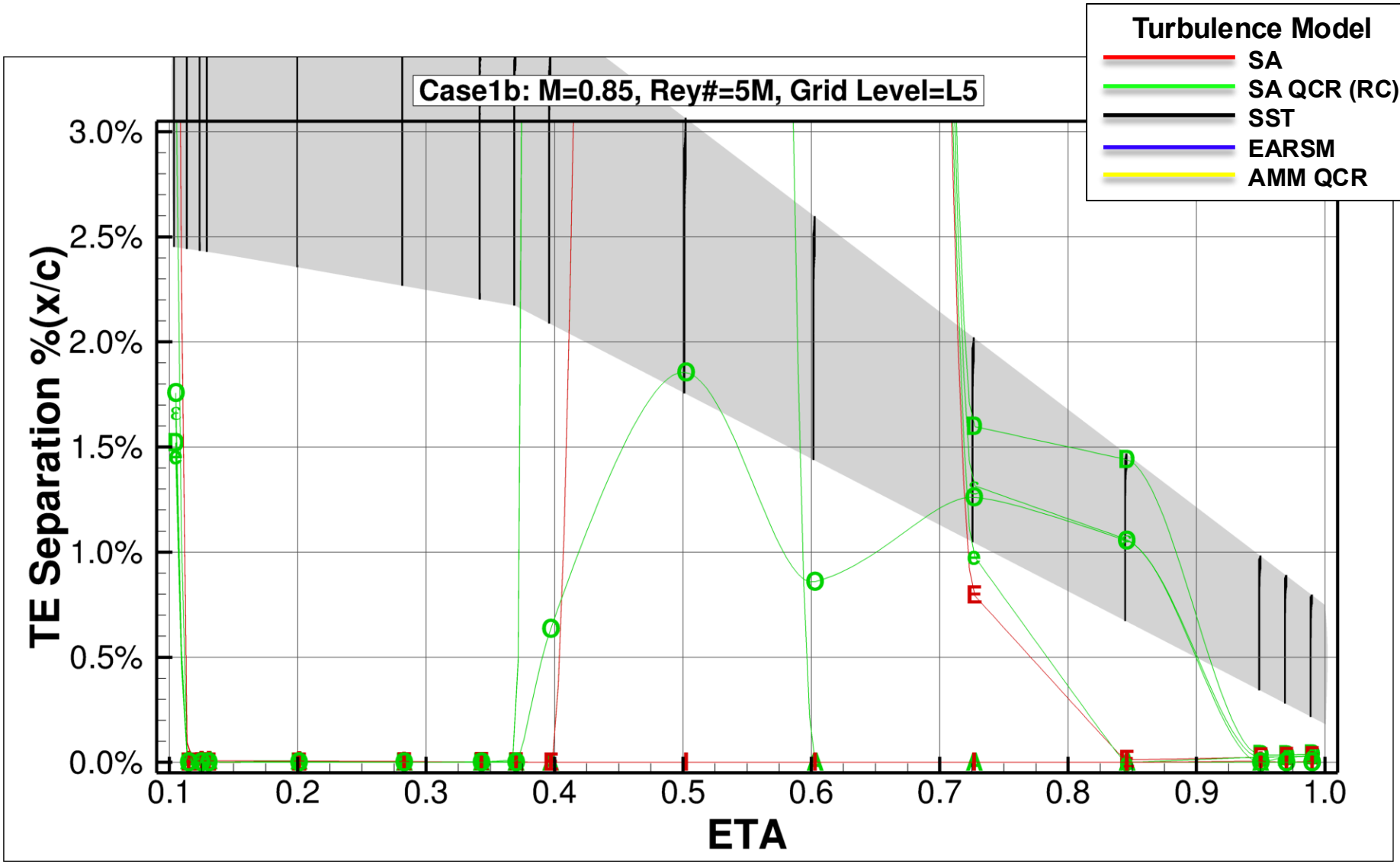
M = 0.85 | C_L = 0.58 | Rey# = 5M

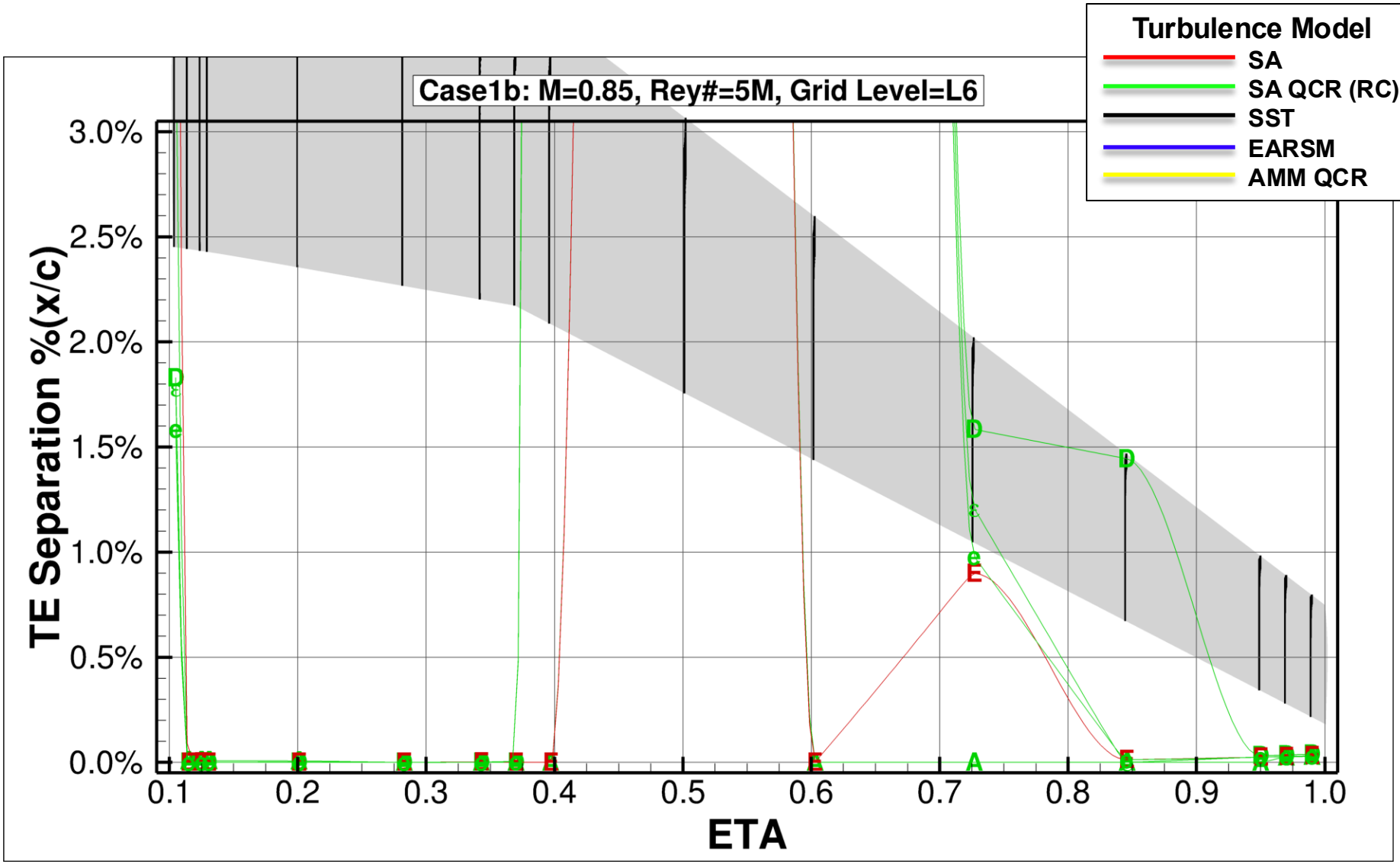

Case1b: M=0.85, Rey#=5M, Grid Level=L1
Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
TE Separation %(x/c)
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA


Case1b: M=0.85, Rey#=5M, Grid Level=L2
Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
TE Separation %(x/c)
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA

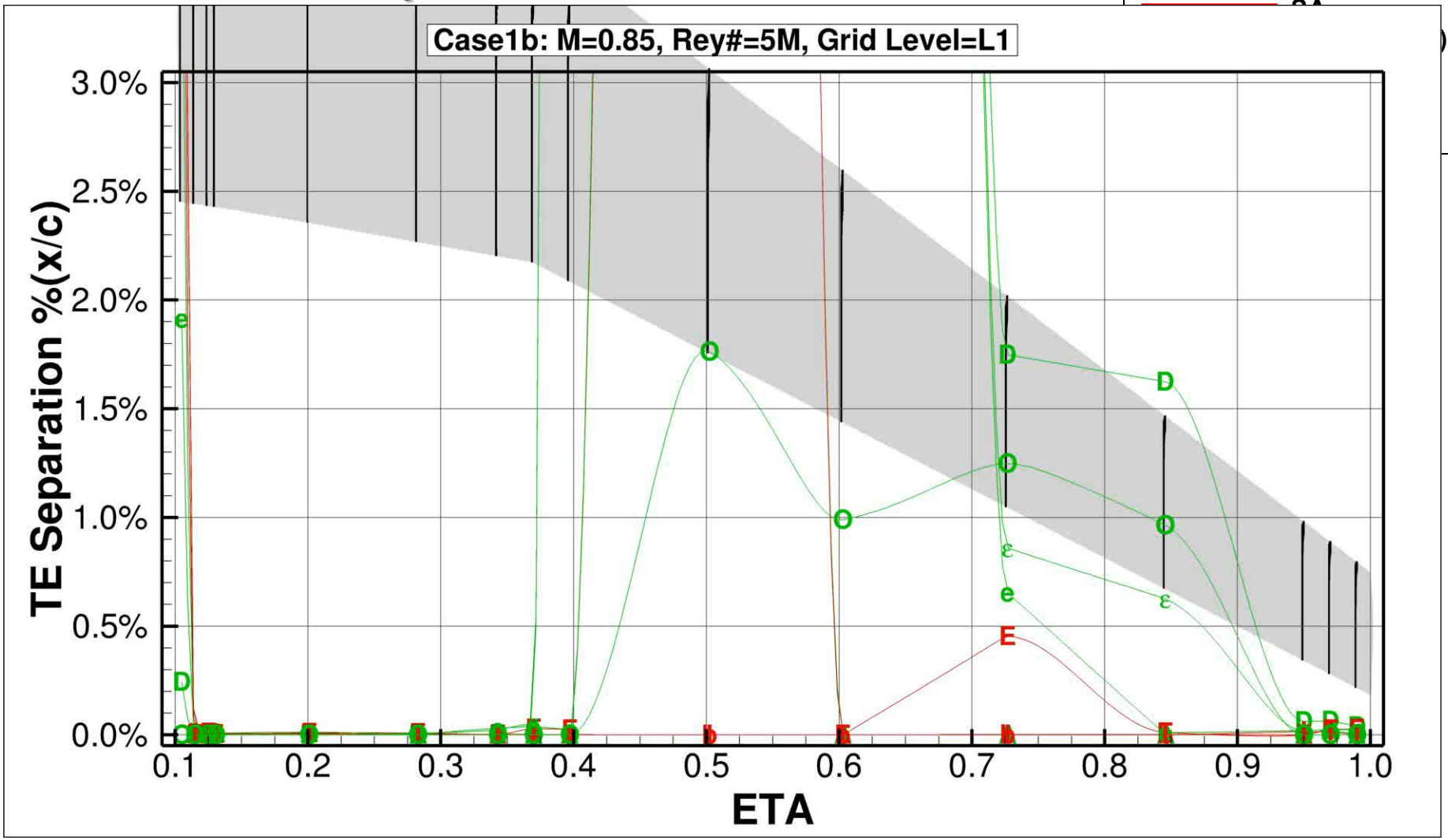

Case1b: M=0.85, Rey#=5M, Grid Level=L3
Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
TE Separation %(x/c)
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA


Case1b: M=0.85, Rey#=5M, Grid Level=L4
Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
TE Separation %(x/c)
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA


Case1b: M=0.85, Rey#=5M, Grid Level=L5
Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
TE Separation %(x/c)
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA


Case1b: M=0.85, Rey#=5M, Grid Level=L6
Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
TE Separation %(x/c)
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA

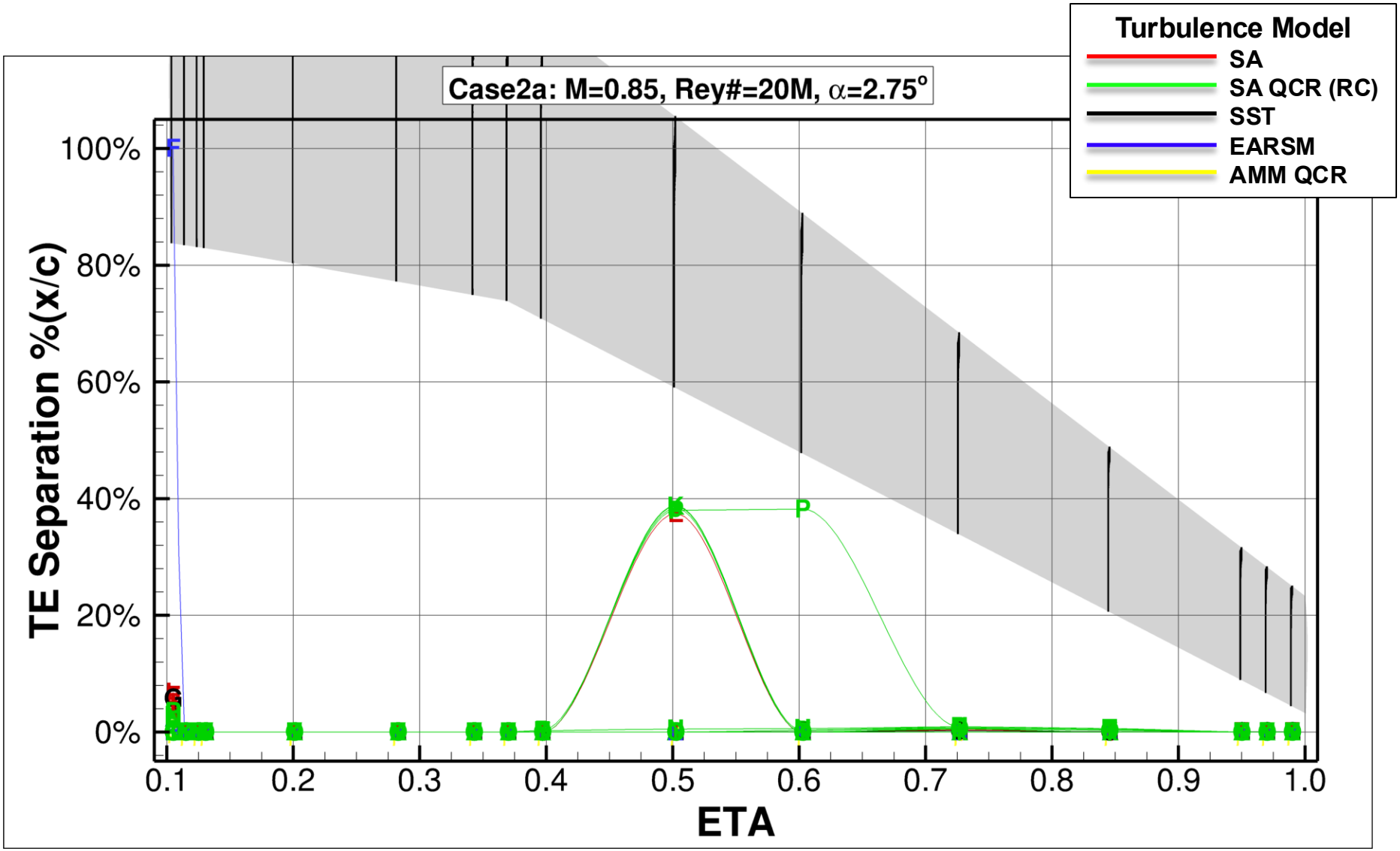
Animated Sweep

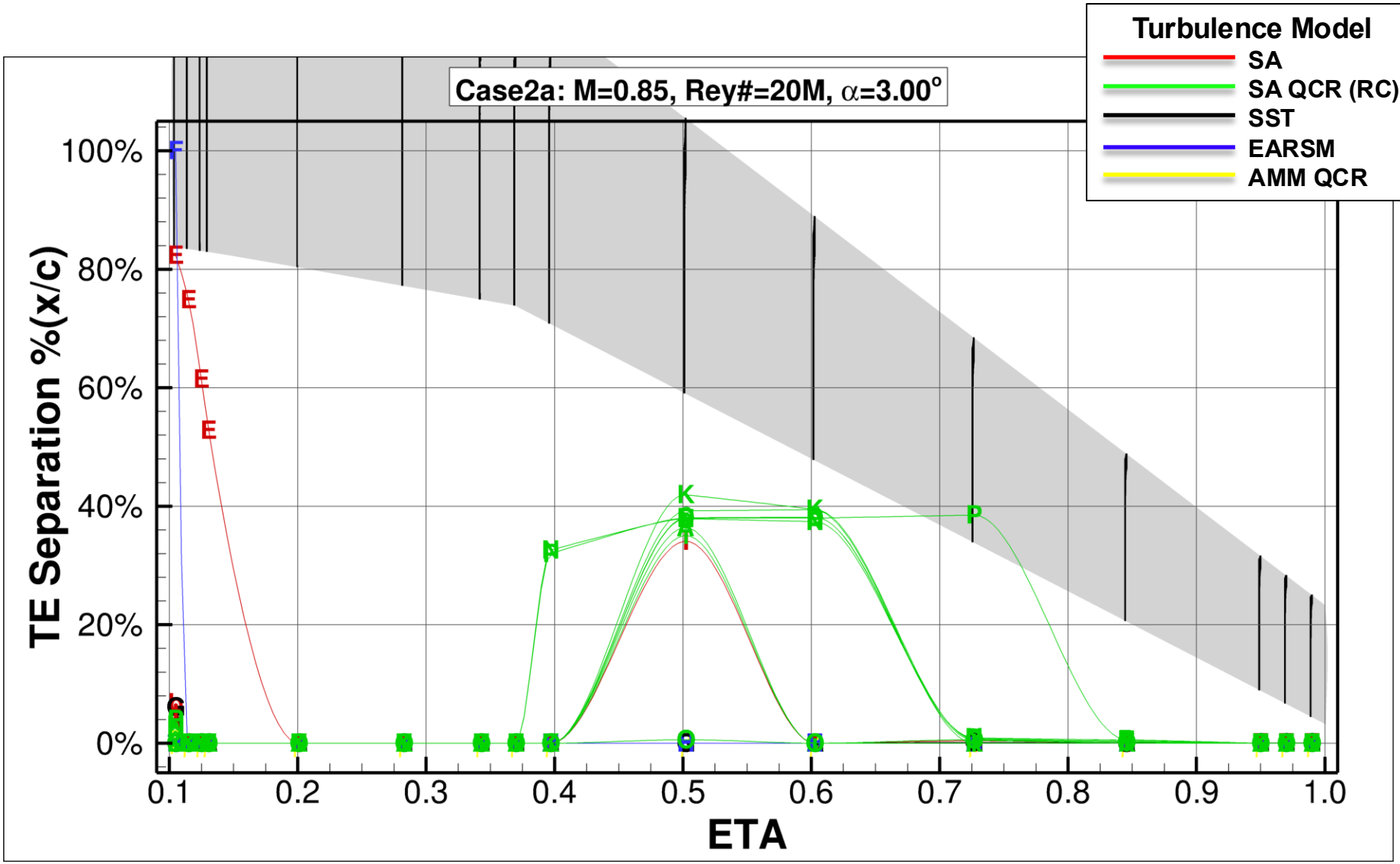


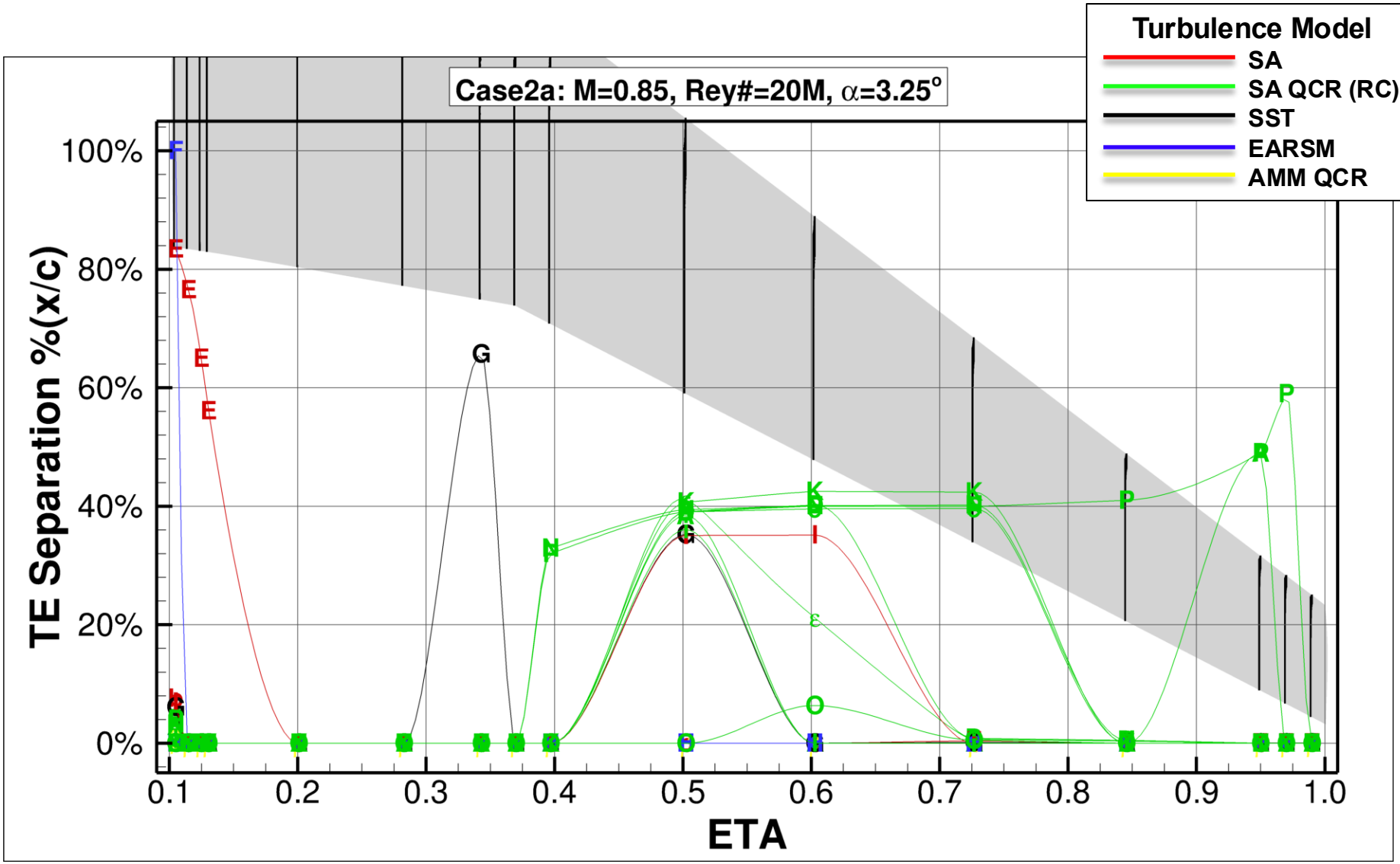
Case 2a

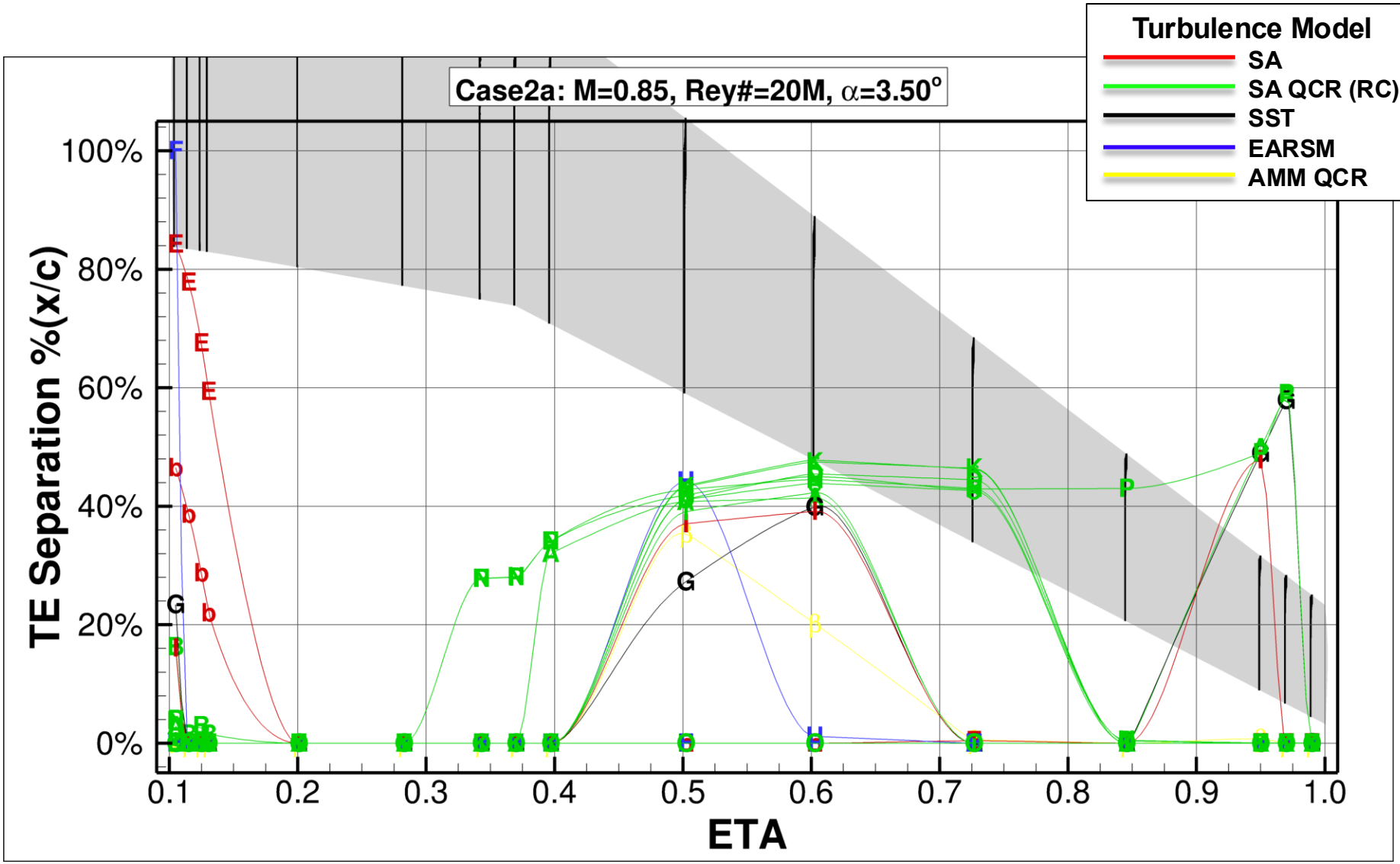
CRM Wing-Body Alpha Sweep

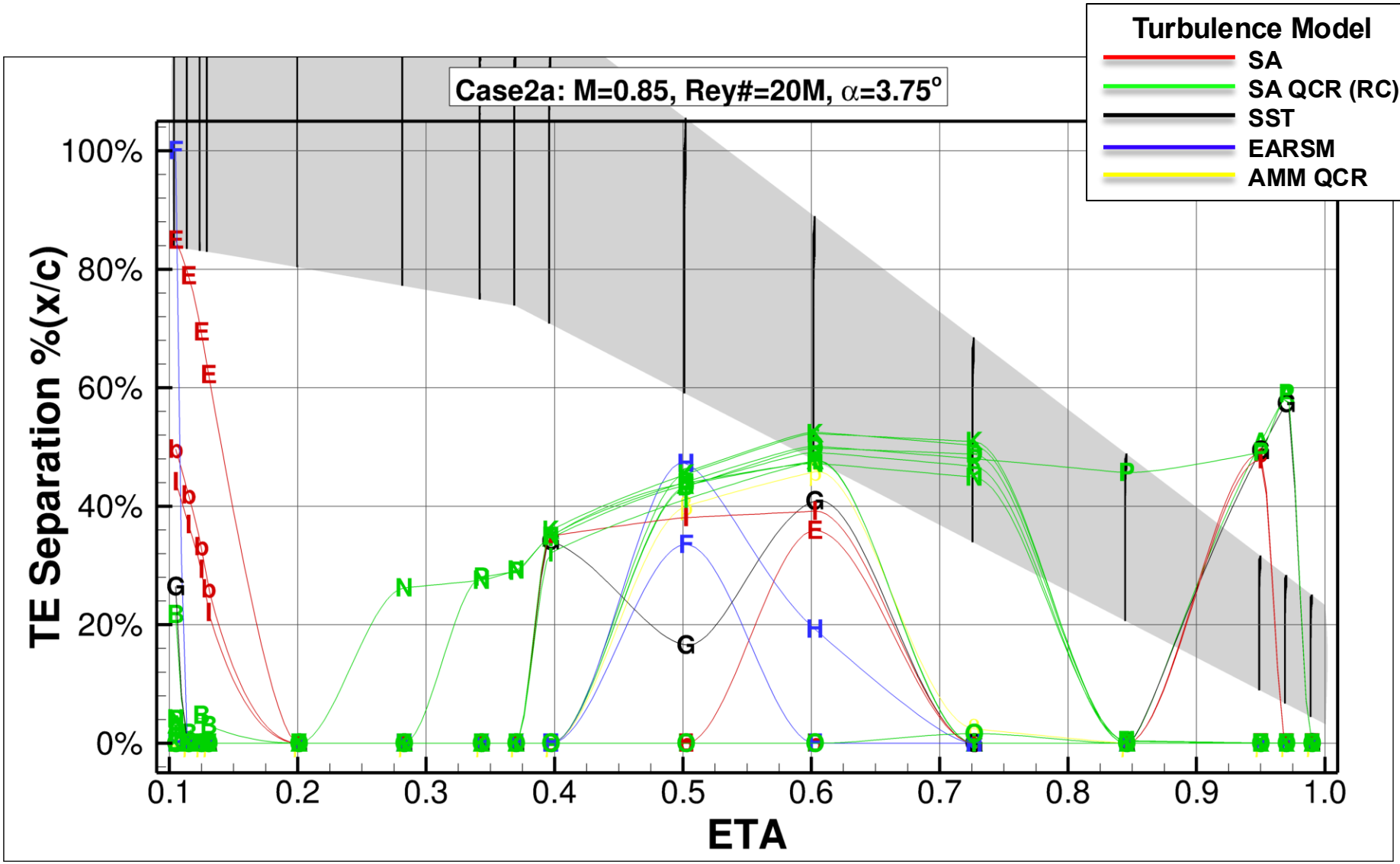
M = 0.85 | α = 2.75–4.25° | Rey# = 20M

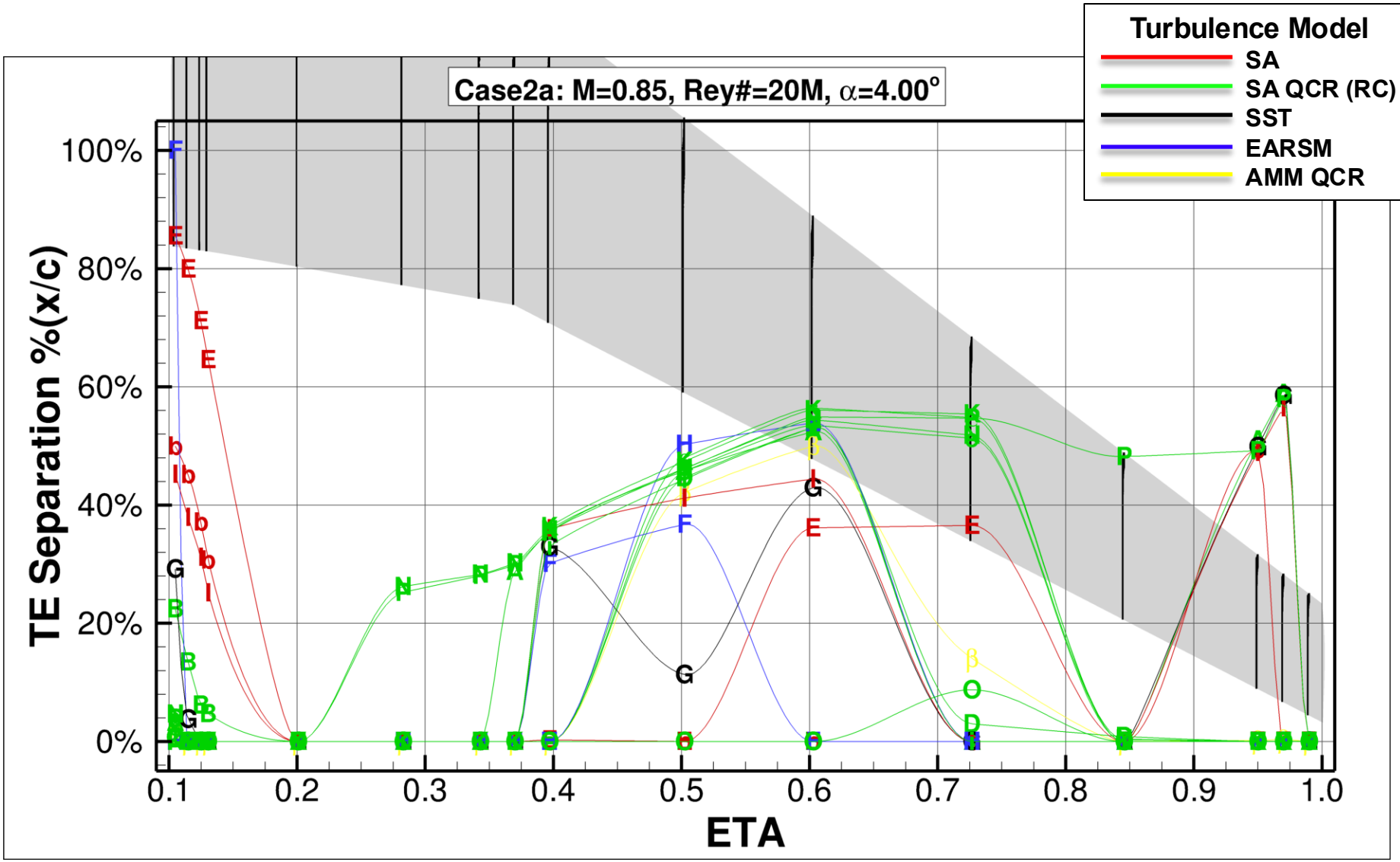

Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
Case2a: M=0.85, Rey#=20M, α=2.75°
TE Separation %(x/c)
100%
80%
60%
40%
20%
0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA
F
K
P

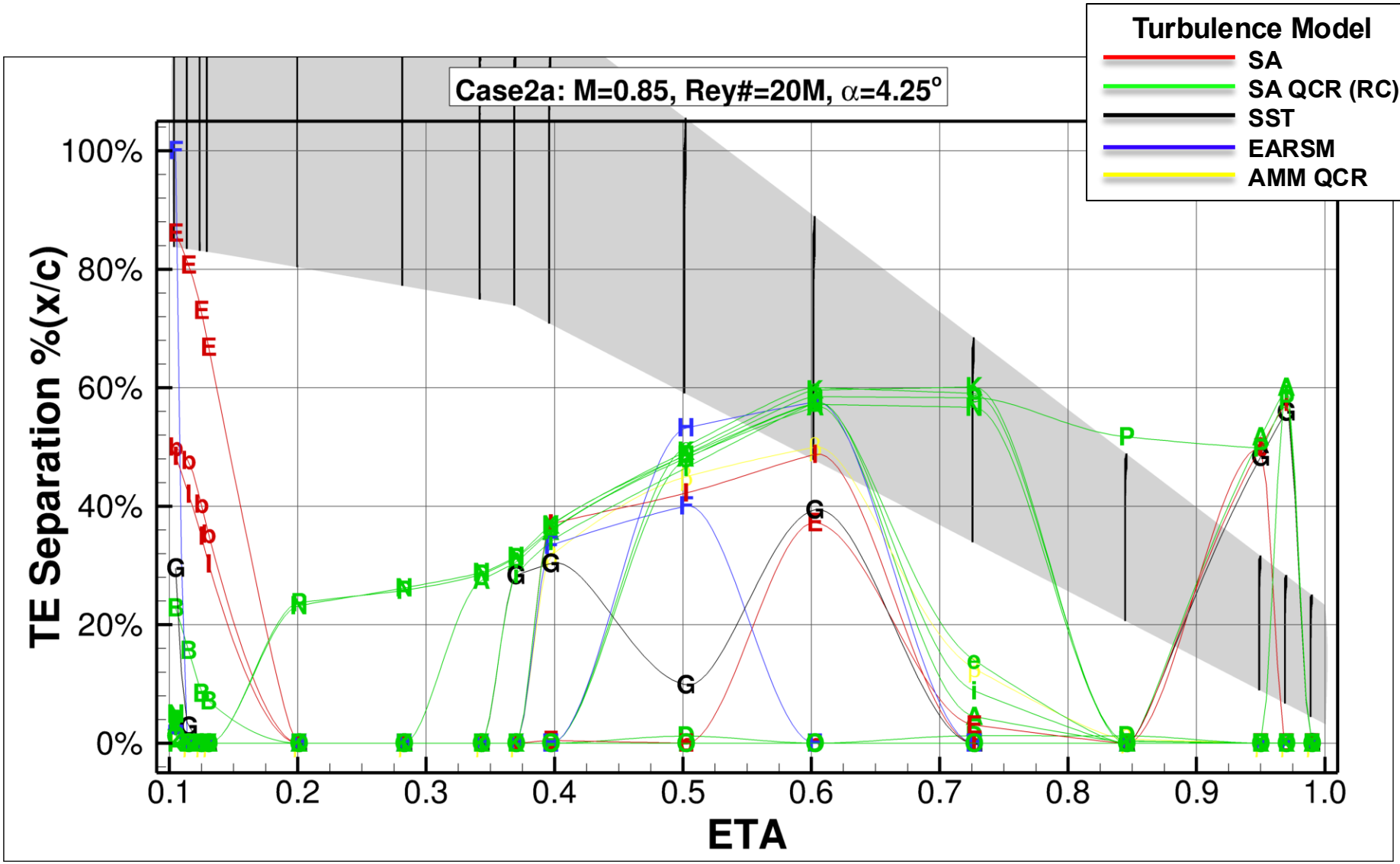

Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
Case2a: M=0.85, Rey#=20M, α=3.00°
TE Separation %(x/c)
100%
80%
60%
40%
20%
0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA


Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
Case2a: M=0.85, Rey#=20M, α=3.25°
TE Separation %(x/c)
100%
80%
60%
40%
20%
0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA

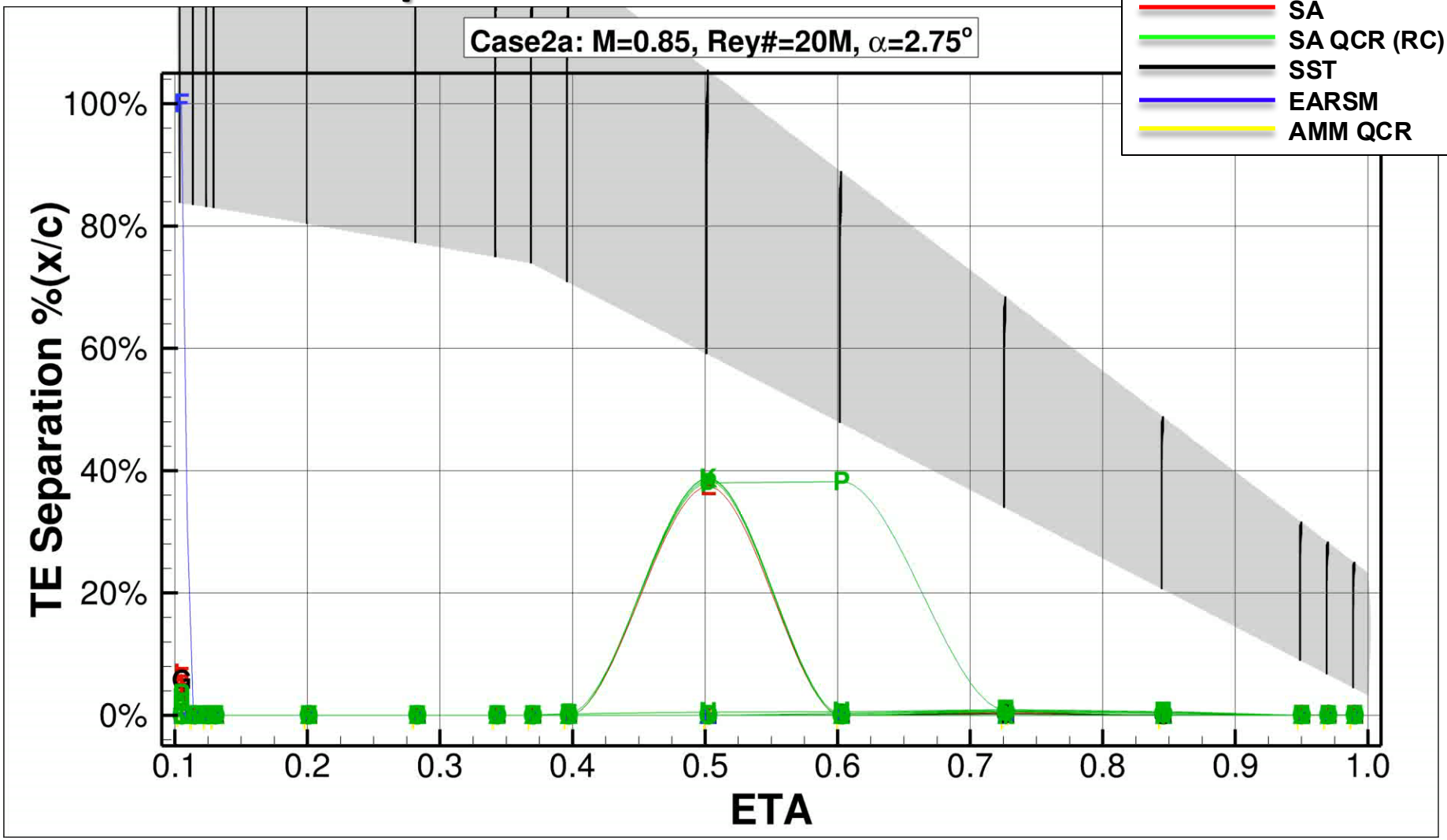

Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
Case2a: M=0.85, Rey#=20M, α=3.50°
TE Separation %(x/c)
100%
80%
60%
40%
20%
0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA


Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
Case2a: M=0.85, Rey#=20M, α=3.75°
TE Separation %(x/c)
100%
80%
60%
40%
20%
0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA


Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
Case2a: M=0.85, Rey#=20M, α=4.00°
TE Separation %(x/c)
100%
80%
60%
40%
20%
0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA


Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
Case2a: M=0.85, Rey#=20M, α=4.25°
TE Separation %(x/c)
100%
80%
60%
40%
20%
0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA

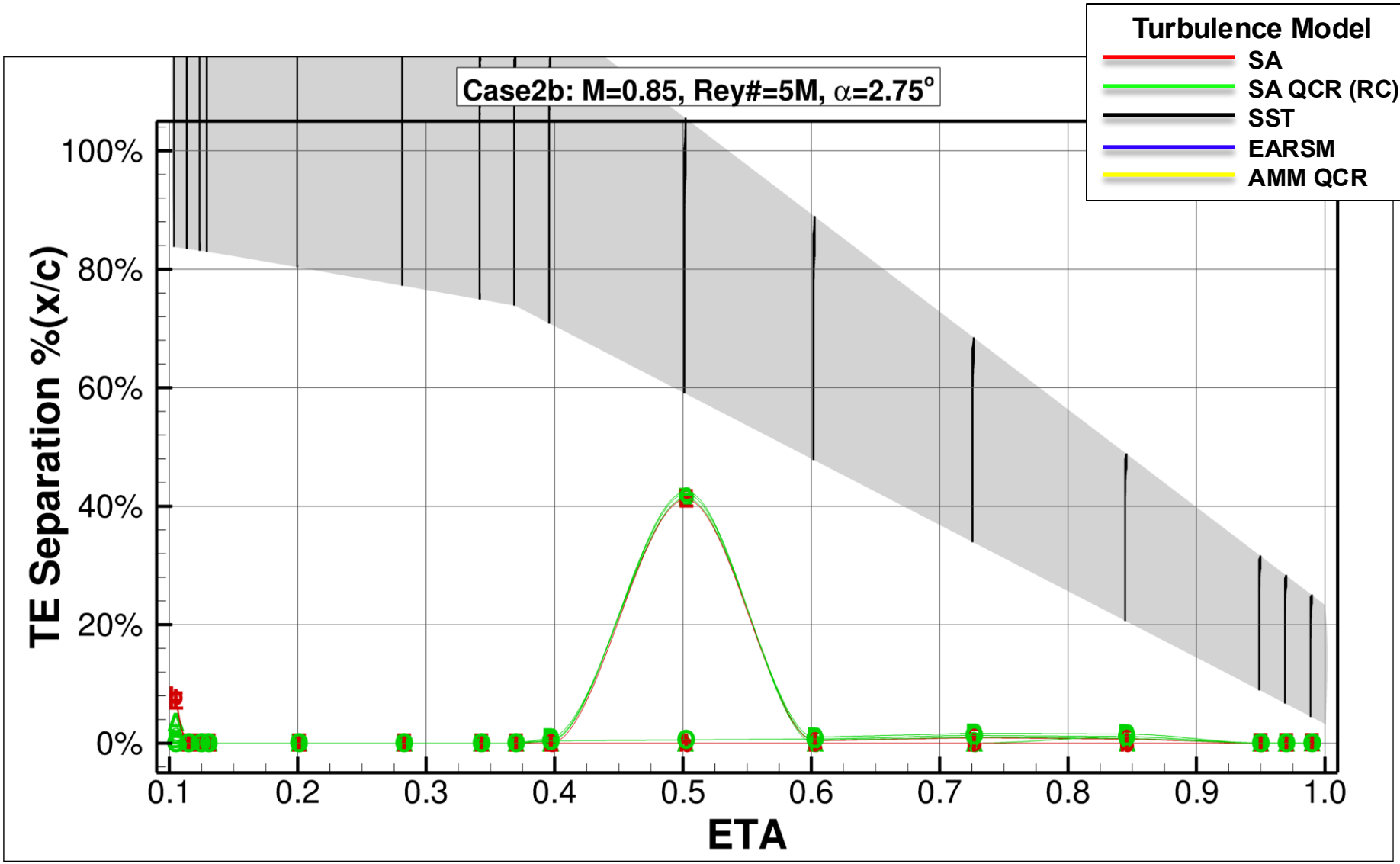
Animated Sweep

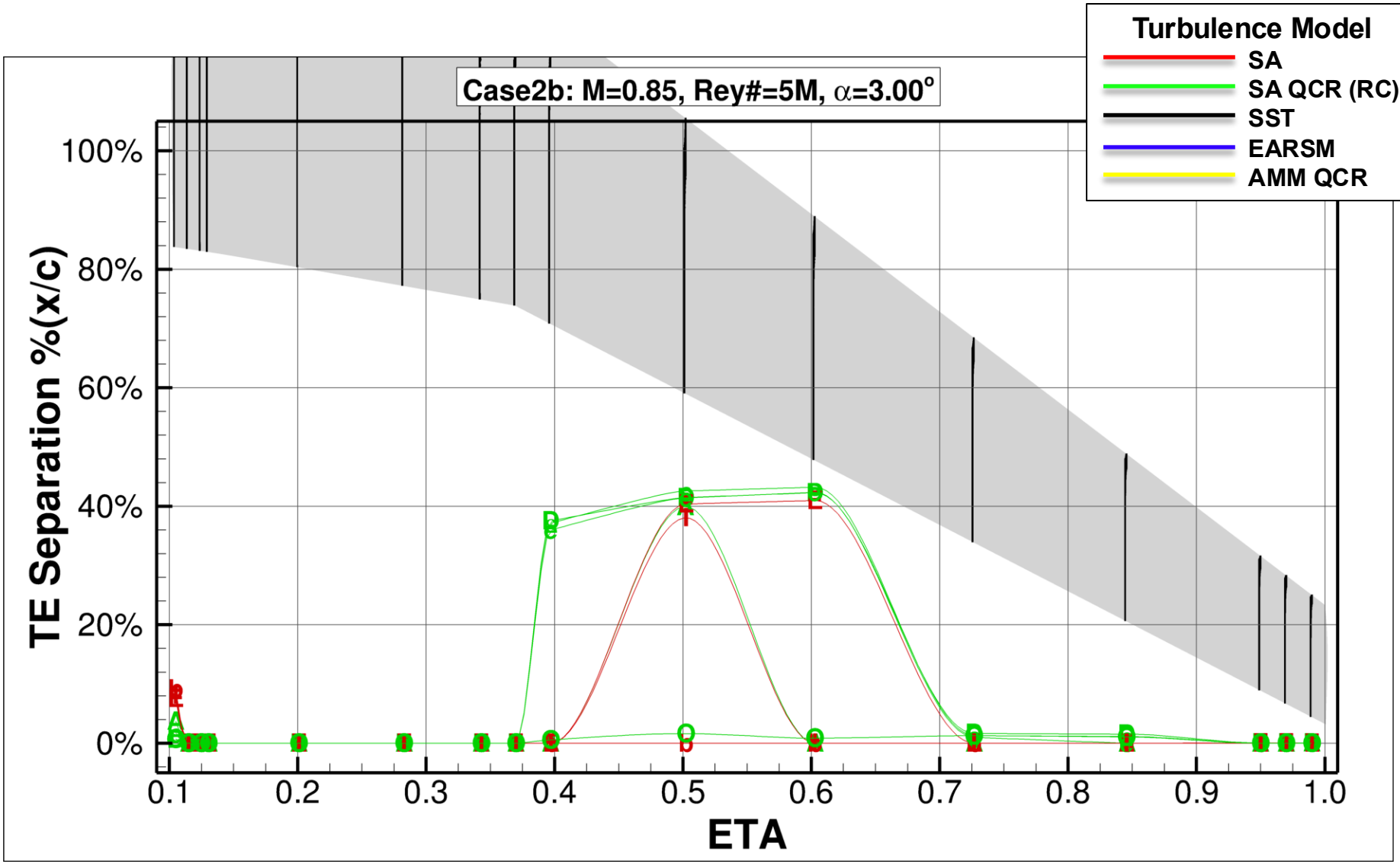


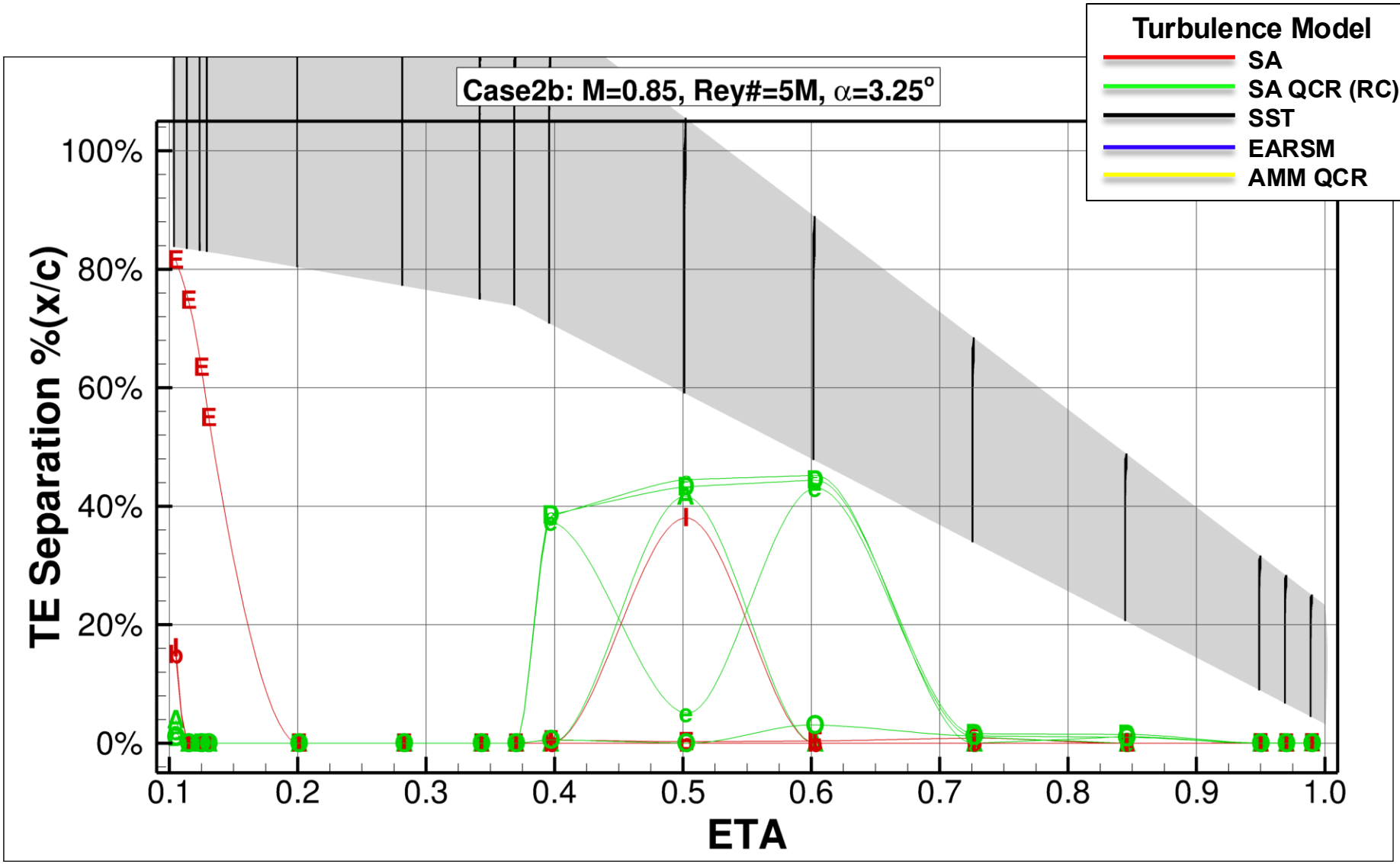
Case 2b

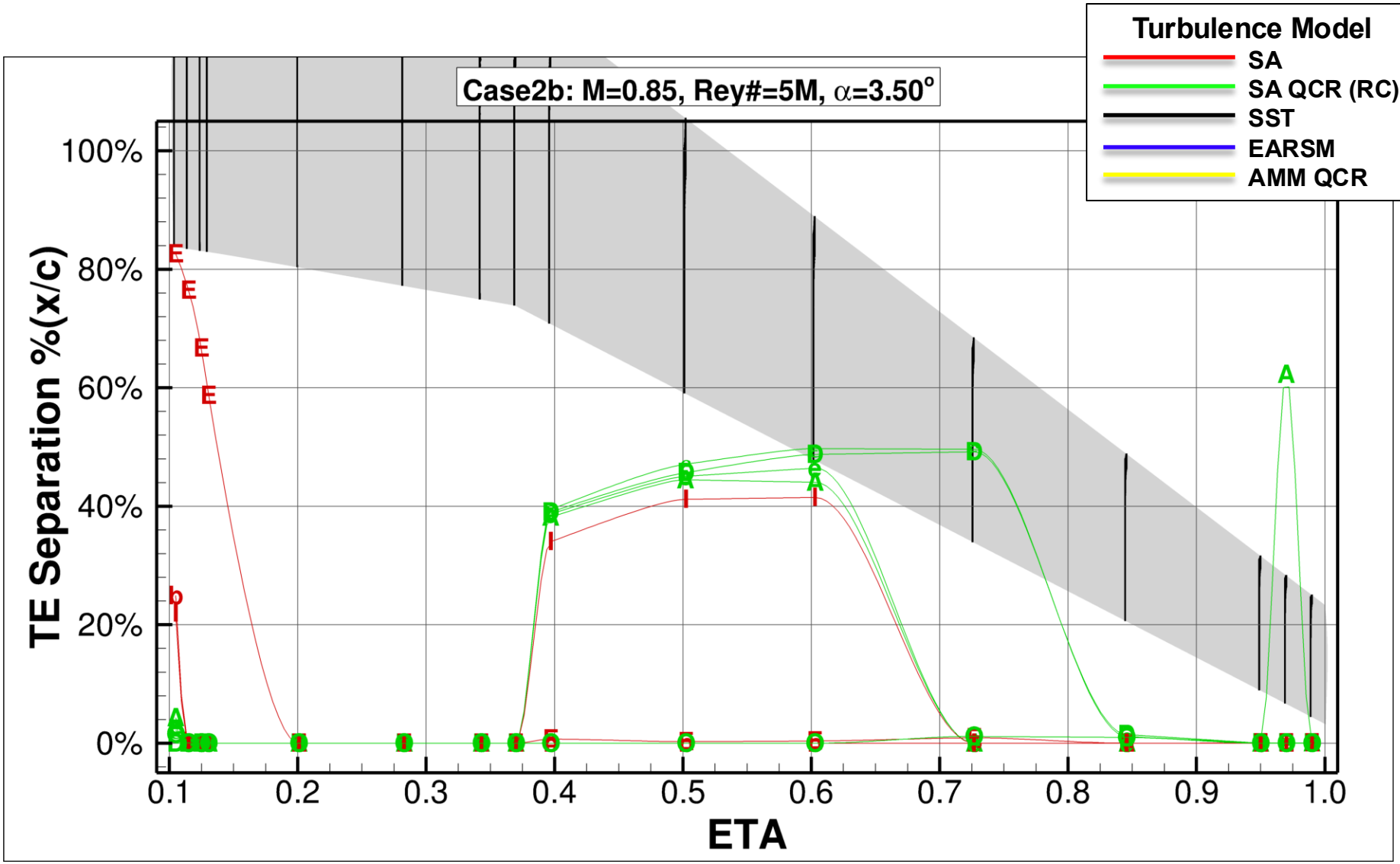
CRM Wing-Body Alpha Sweep

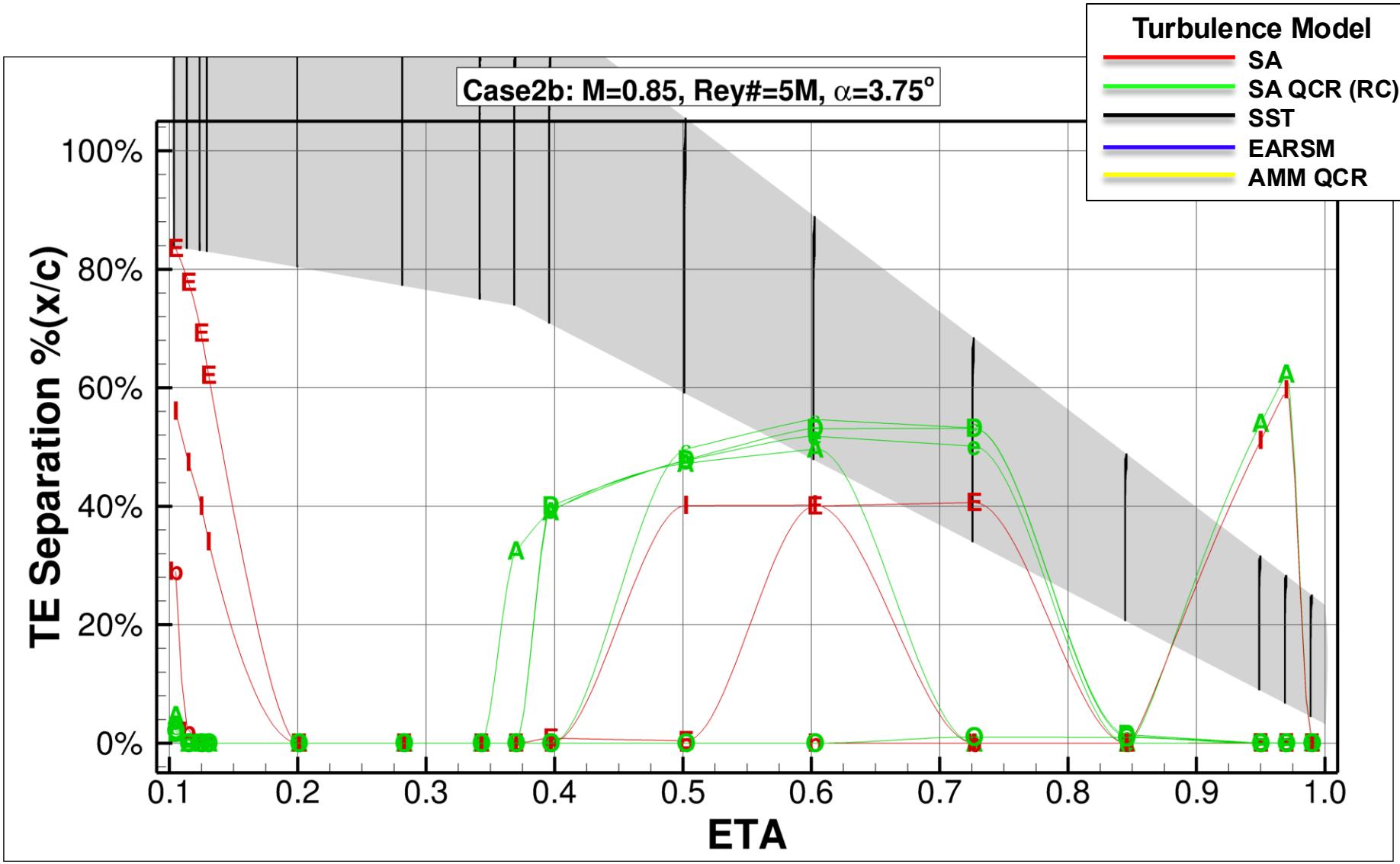
M = 0.85 |α = 2.75–4.25° |Rey# = 5M

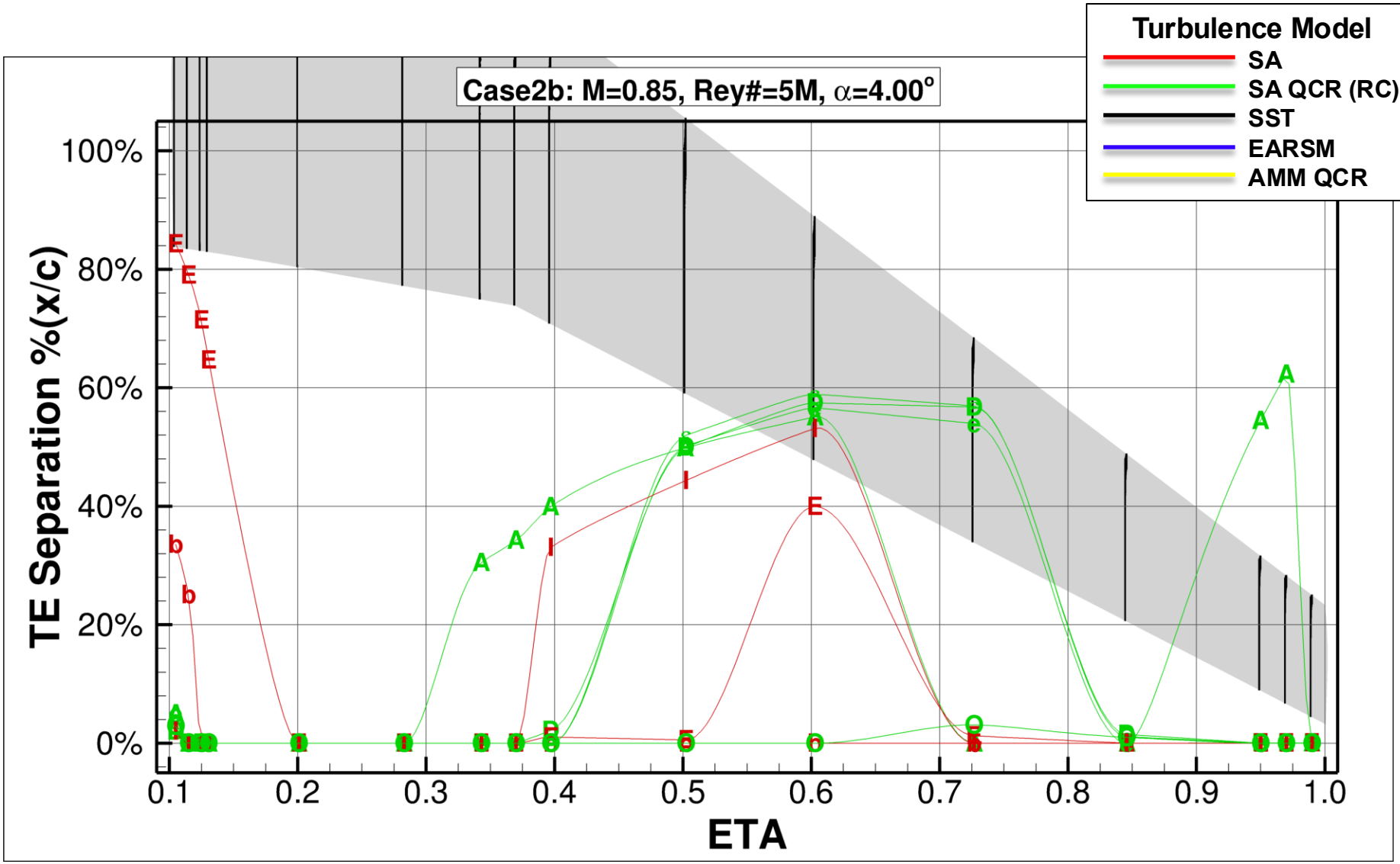

Case2b: M=0.85, Rey#=5M, α=2.75°
Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
TE Separation %(x/c)
100%
80%
60%
40%
20%
0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA

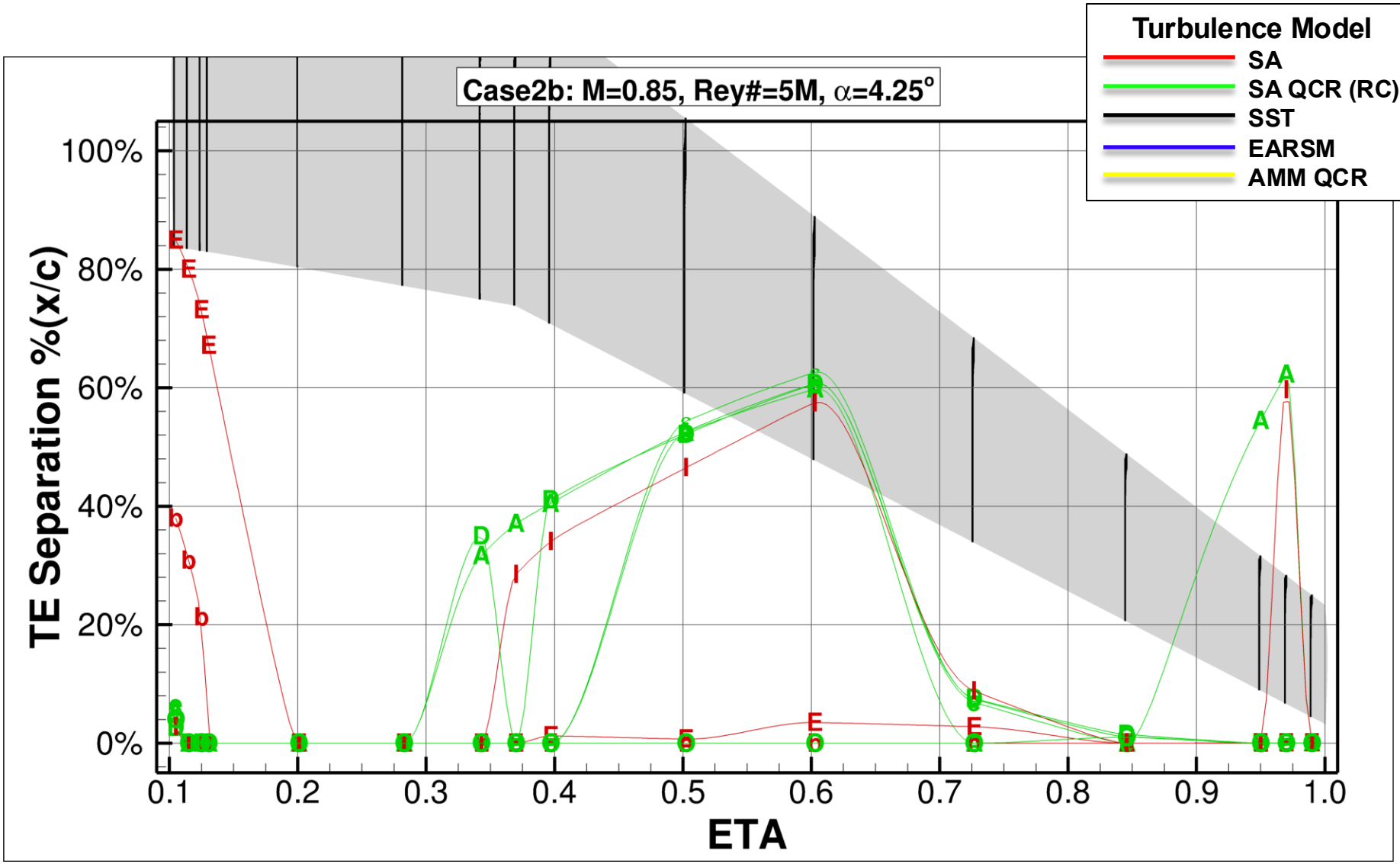

Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
Case2b: M=0.85, Rey#=5M, α=3.00°
TE Separation %(x/c)
100%
80%
60%
40%
20%
0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA


Case2b: M=0.85, Rey#=5M, α=3.25°
Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
TE Separation %(x/c)
100%
80%
60%
40%
20%
0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA

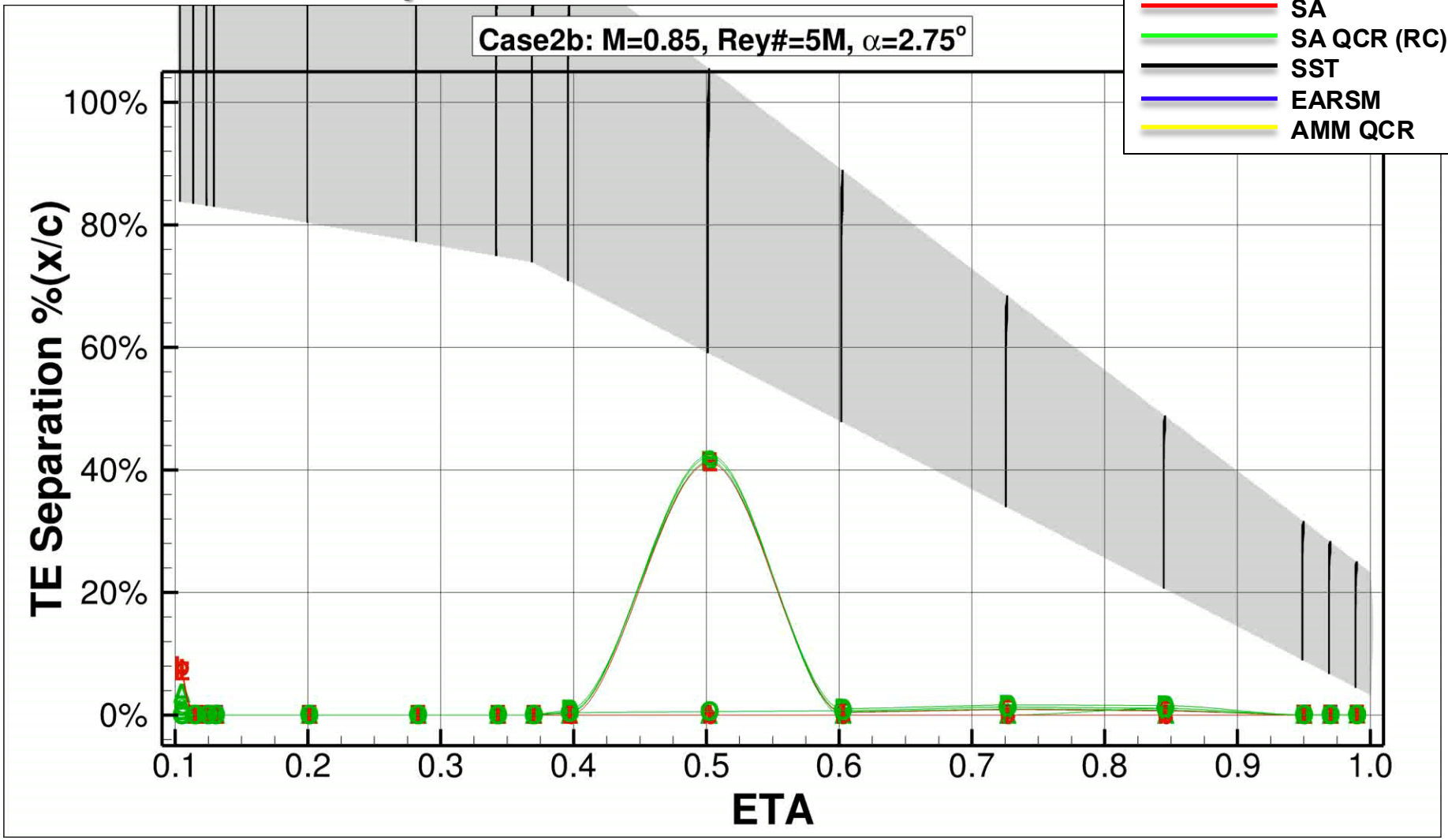

Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
Case2b: M=0.85, Rey#=5M, α=3.50°
TE Separation %(x/c)
100%
80%
60%
40%
20%
0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA


Case2b: M=0.85, Rey#=5M, α=3.75°
Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
TE Separation %(x/c)
100%
80%
60%
40%
20%
0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA


Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
Case2b: M=0.85, Rey#=5M, α=4.00°
TE Separation %(x/c)
100%
80%
60%
40%
20%
0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA


Case2b: M=0.85, Rey#=5M, α=4.25°
Turbulence Model
SA
SA QCR (RC)
SST
EARSM
AMM QCR
TE Separation %(x/c)
100%
80%
60%
40%
20%
0%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ETA

Animated Sweep



Conclusions:

- Extracting "TE" Separation is difficult to identify generally
  - Requires judgement about how to handle sections with a separation bubble at the shock extends far enough to be called TE separation and
- Not enough data set for turbulence models other than SA-QCR to make judgments
- Case 1
  - Reduced spread (within matching turbulence model) as grid density is increased
- Case 2
  - Fairly good agreement between Yehudi break and eta=0.70.
  - Much more disagreement on inboard wing and wing tip