Evaluation of Morrison, Milbrandt & Yau, and Thompson microphysics schemes in a suite of high-resolution, idealized supercell simulations

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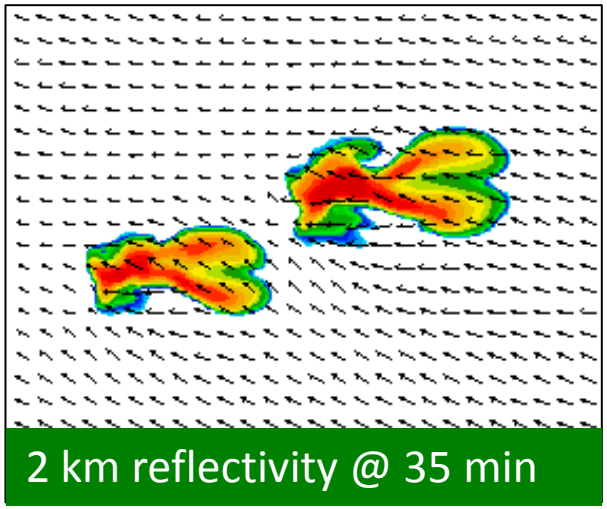
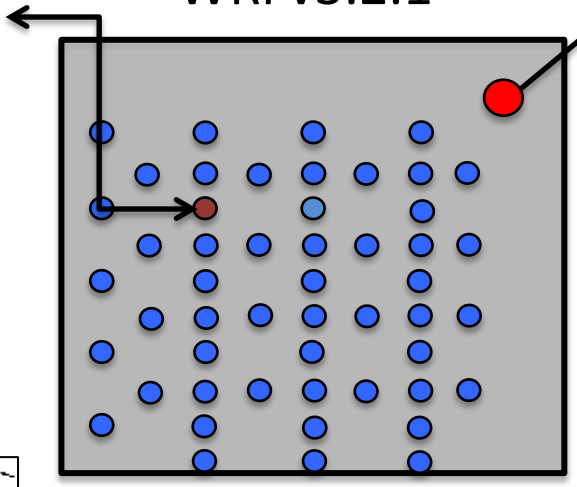
Framework for Microphysics Evaluation: Cell Interaction Study

Control cell + second cell

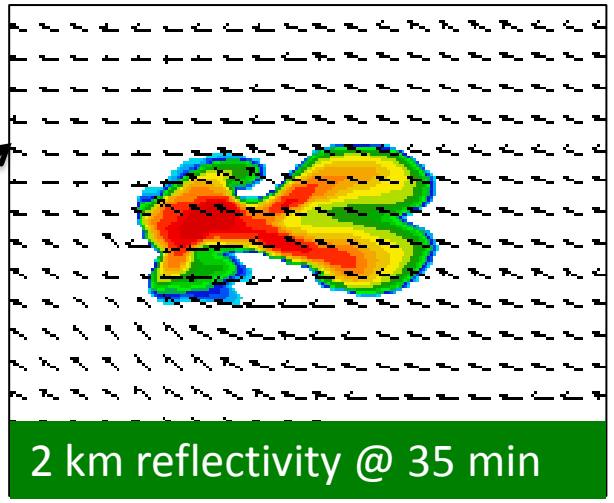


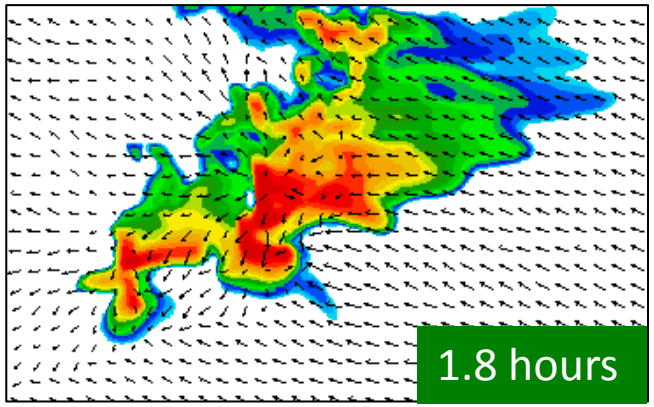
WRFv3.2.1

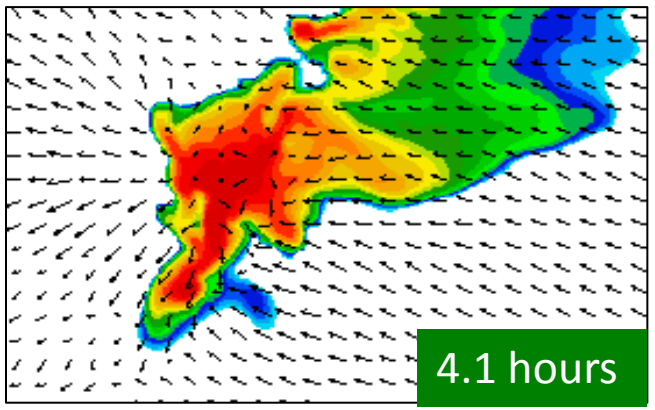


MP: Thompson et al. 2007 (option 98)

Control – Single cell







Microphysics Schemes

mp_physics	Scheme	Cores	Mass Variables	Number Variables
8	Thompson	ARW/NMM	Qc Qr Qi Qs Qg	Ni Nr
9	Milbrandt-Yau	ARW	Qc Qr Qi Qs Qg Qh	Nc Nr Ni Ns Ng Nh
10	Morrison	ARW (Chem)	Qc Qr Qi Qs Qg/h	Nr Ni Ns Ng/h

Changes made between WRF ARW v3.2.1 and v3.3

Morrison

* Modified fallspeed below the lowest level of precipitation; prevents potential for spurious accumulation of precipitation during sub-stepping for sedimentation
* Bug fix to latent heat release due to collisions of cloud ice with rain

Thompson

* Fixed bug involving the removal of graupel with rain and snow collisions
* Rain evaporation correction
* New method to determine graupel Y-intercept parameter

Milbrandt & Yau

* corrected latent heat constants in thermodynamic functions (ABi and ABw) for sublimation and evaporation
* properly initialized variables No_g and No_h
* changed max ice crystal size (fallspeed) to 5 mm (2 m s-1)
* imposed maximum ice number concentration of 1.e+7 m-3
* removed unused supersaturation reduction

-WRF Users Guide

Procedure

7 simulations (single-cell control):

- WRFv3.2.1 – Morrison, M-Y, and Thompson
- WRFv3.3 – Morrison, Morrison-H, M-Y, and Thompson

Additional simulations (single-cell control):

- WRFv3.3 (TKE) – Morrison-H, M-Y, and Thompson

Model Set-up

- WRF ARW v3.2.1 and WRF ARW v3.3
- 138x138 km domain
- Δx = 540 meters, Δt = 1.5s
- 90 vertical levels
- First model level @ 46.1 meters, lowest Δz = 92.6 m
- 11 levels to between surface and 1 km, 20 levels up to 2 km
- Free-slip
- 3-D Smagorinsky diffusion
- 5-hour simulations of single-cell control
- Idealized sounding-MM5 simulation of April 19th, 1996 Illinois tornado outbreak
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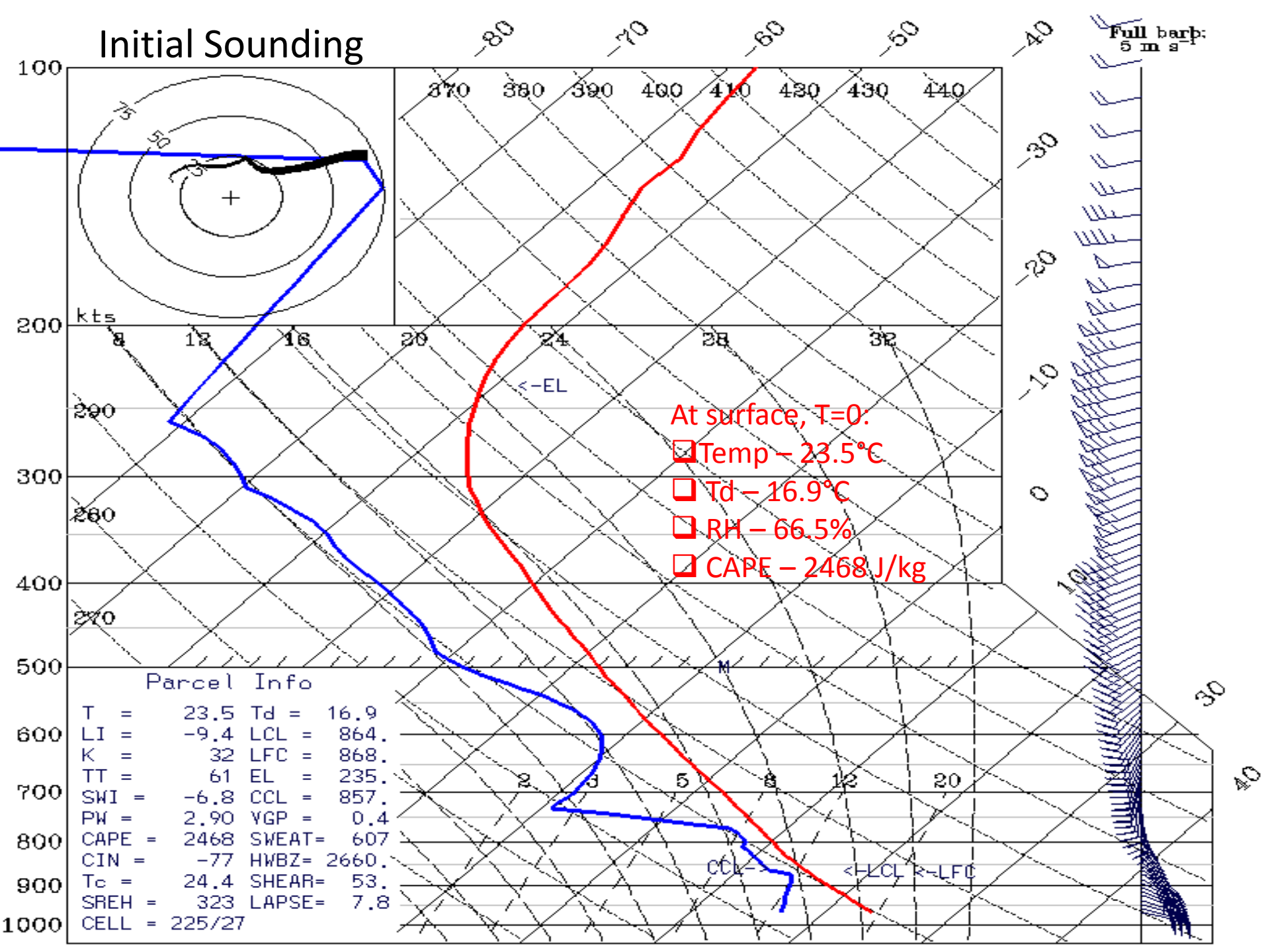
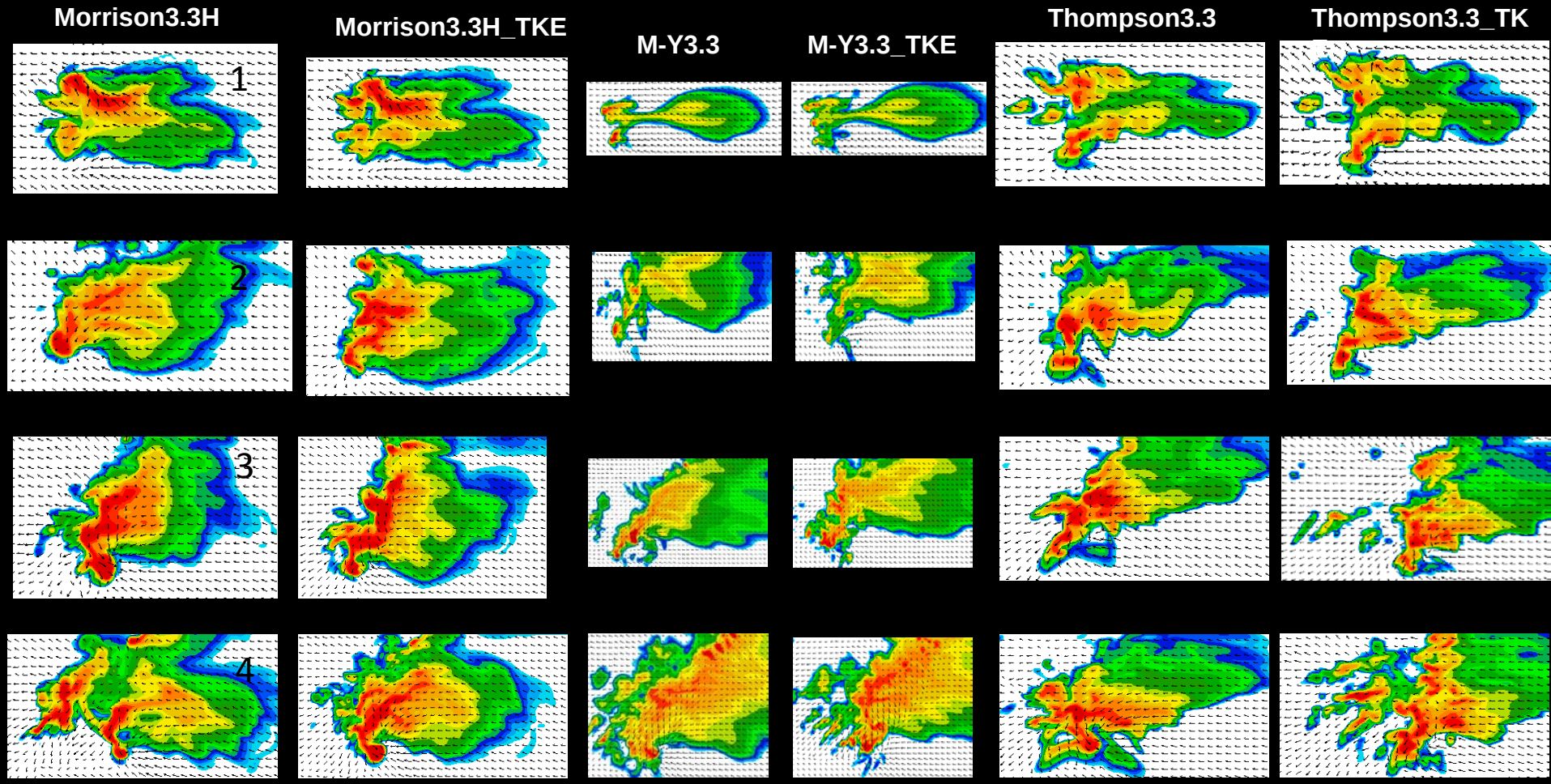
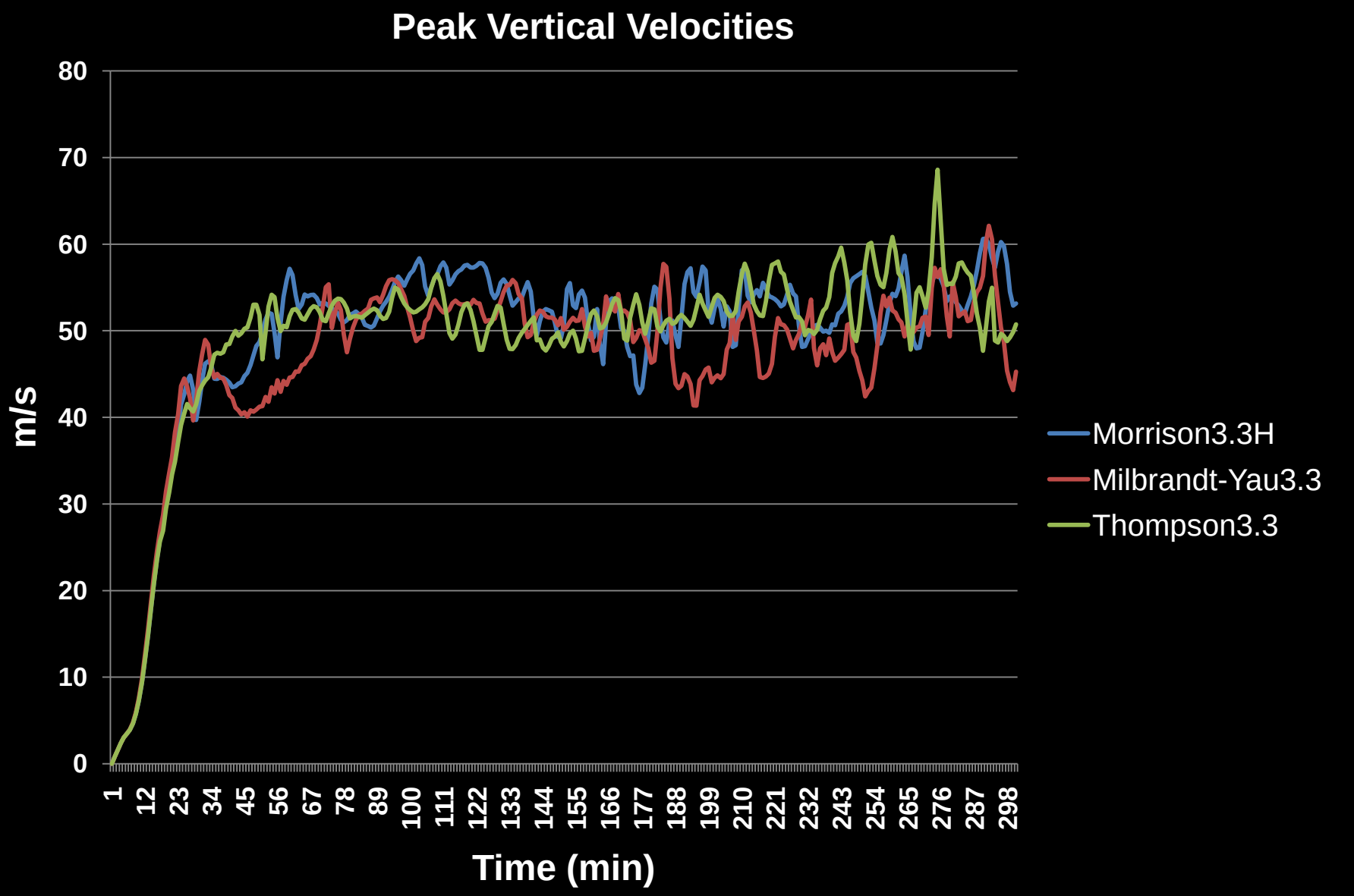
Initial Sounding



Results



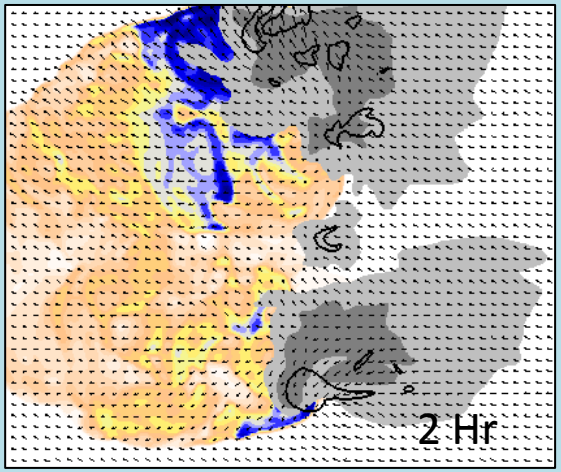
Reflectivity @ 2 km : Hrs 1-4


Peak Vertical Velocities
m/s
80
70
60
50
40
30
20
10
0
1
12
23
34
45
56
67
78
89
100
111
122
133
144
155
166
177
188
199
210
221
232
243
254
265
276
287
298
Time (min)
Morrison3.3H
Milbrandt-Yau3.3
Thompson3.3

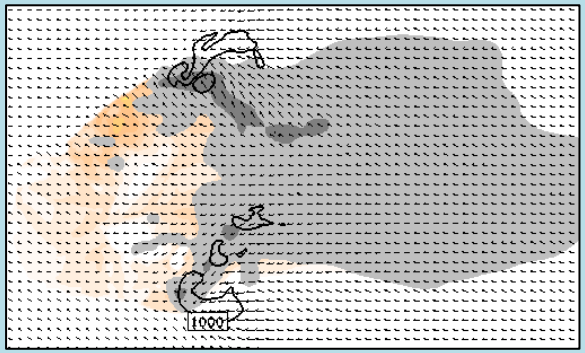
Cold Pool Evolution

Sfc Temp (C) @ 2 and 4.5 Hrs

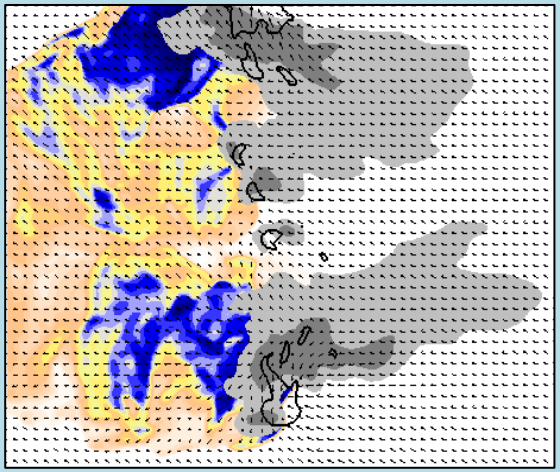
Morrison3.3H

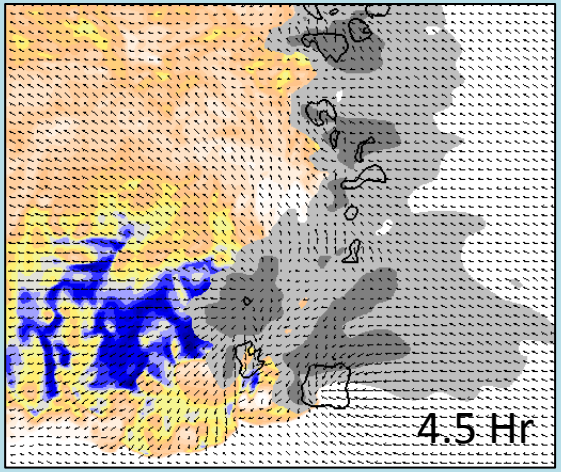


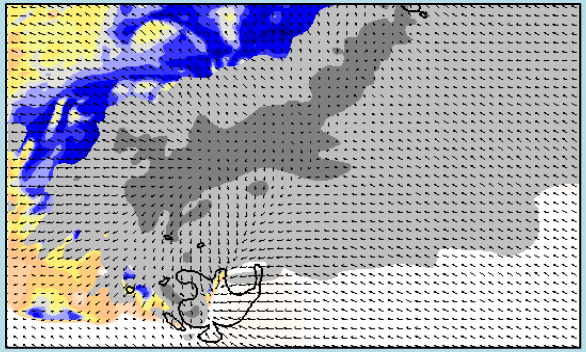
Milbrandt-Yau3.3

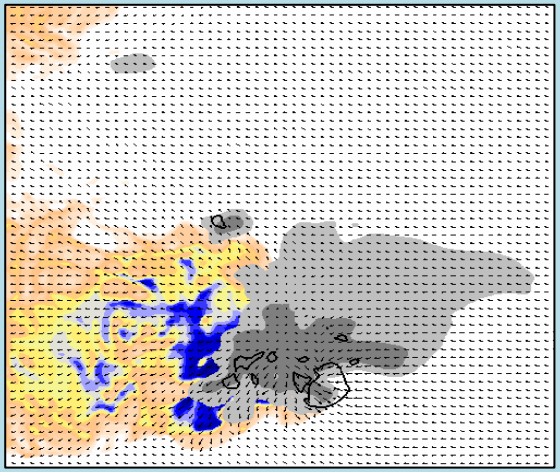


Thompson3.3



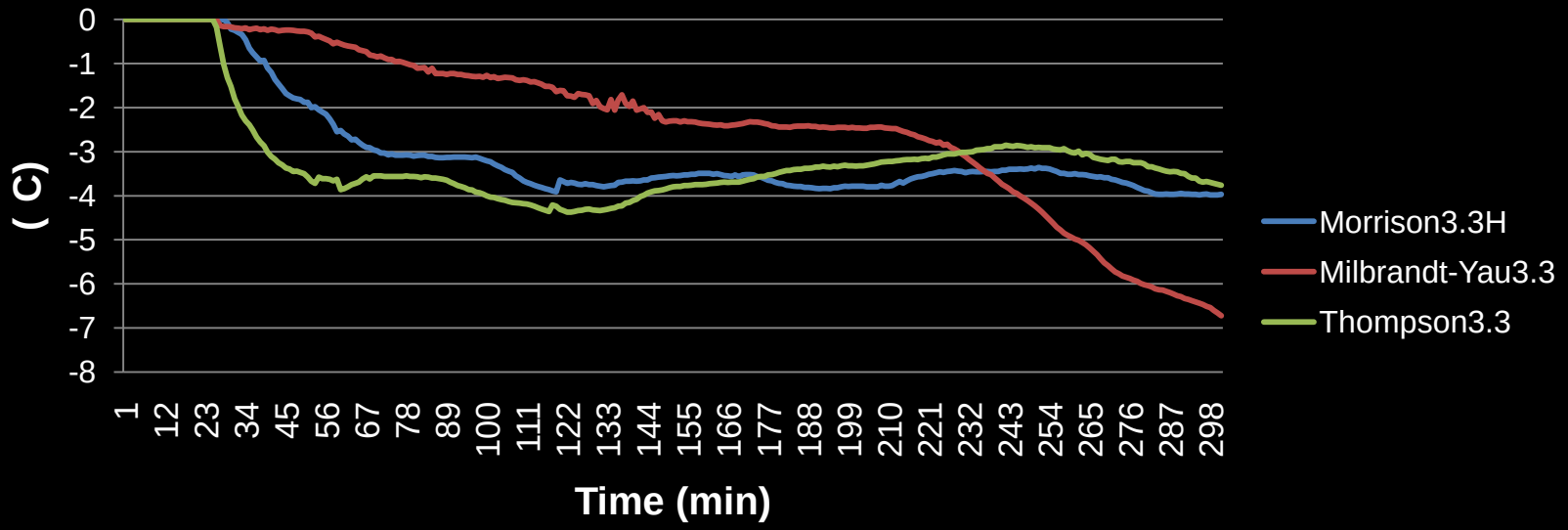




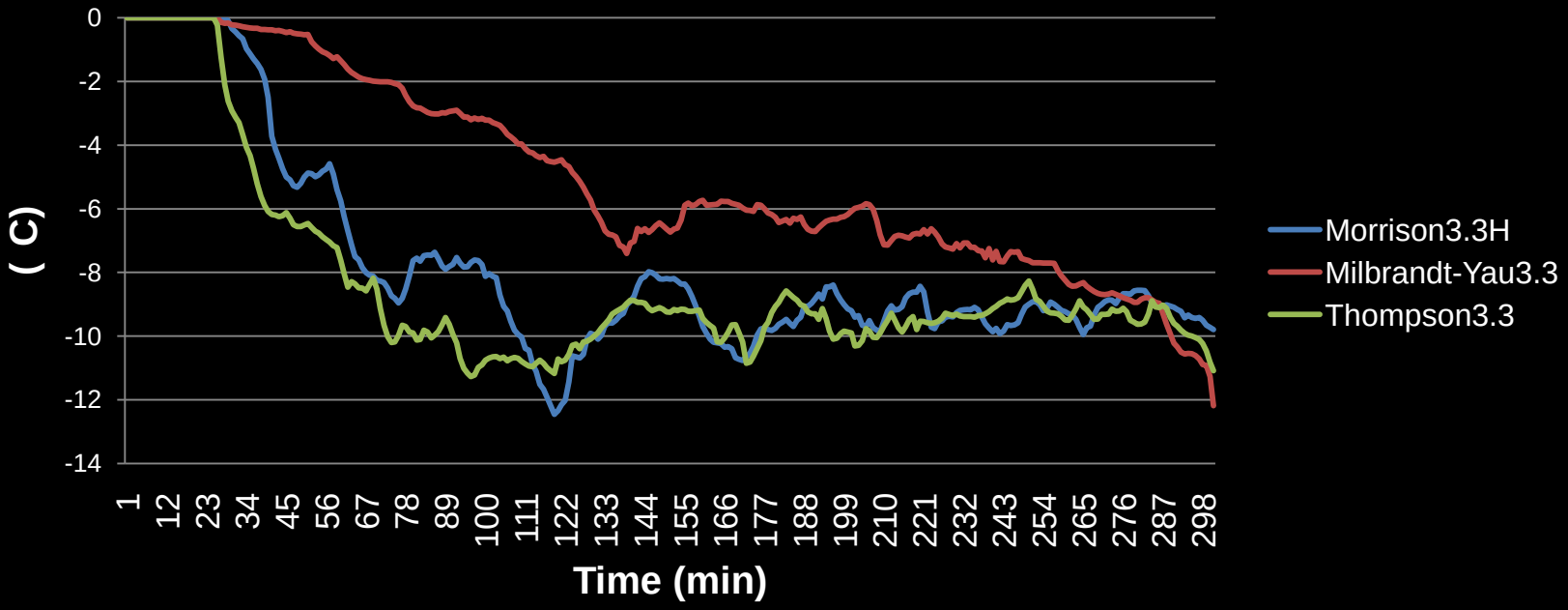


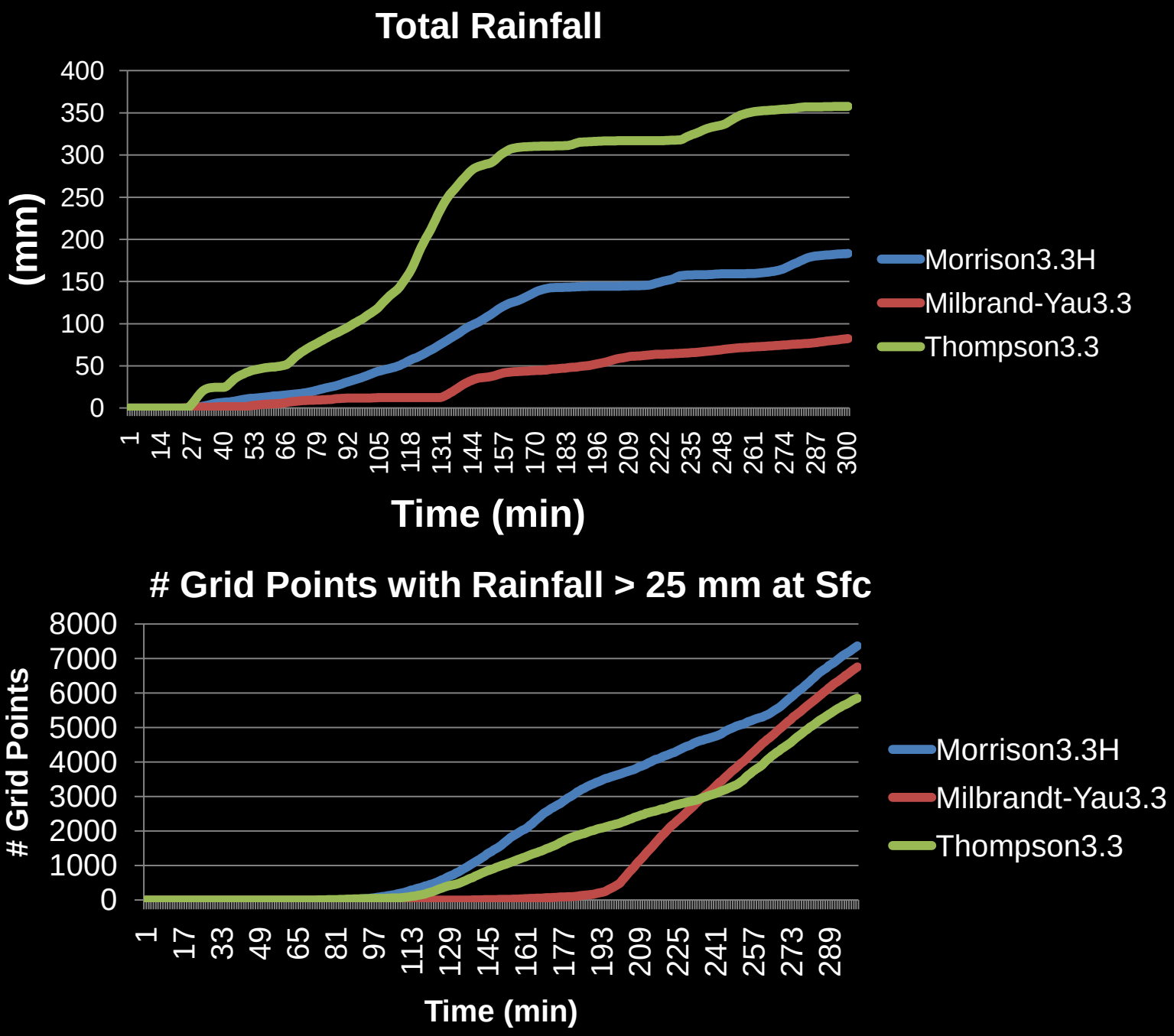
10 and 40 dbz shading; vertical velocity contours > 10 m/s

Surface Cold Pool Average Temp Perturbation

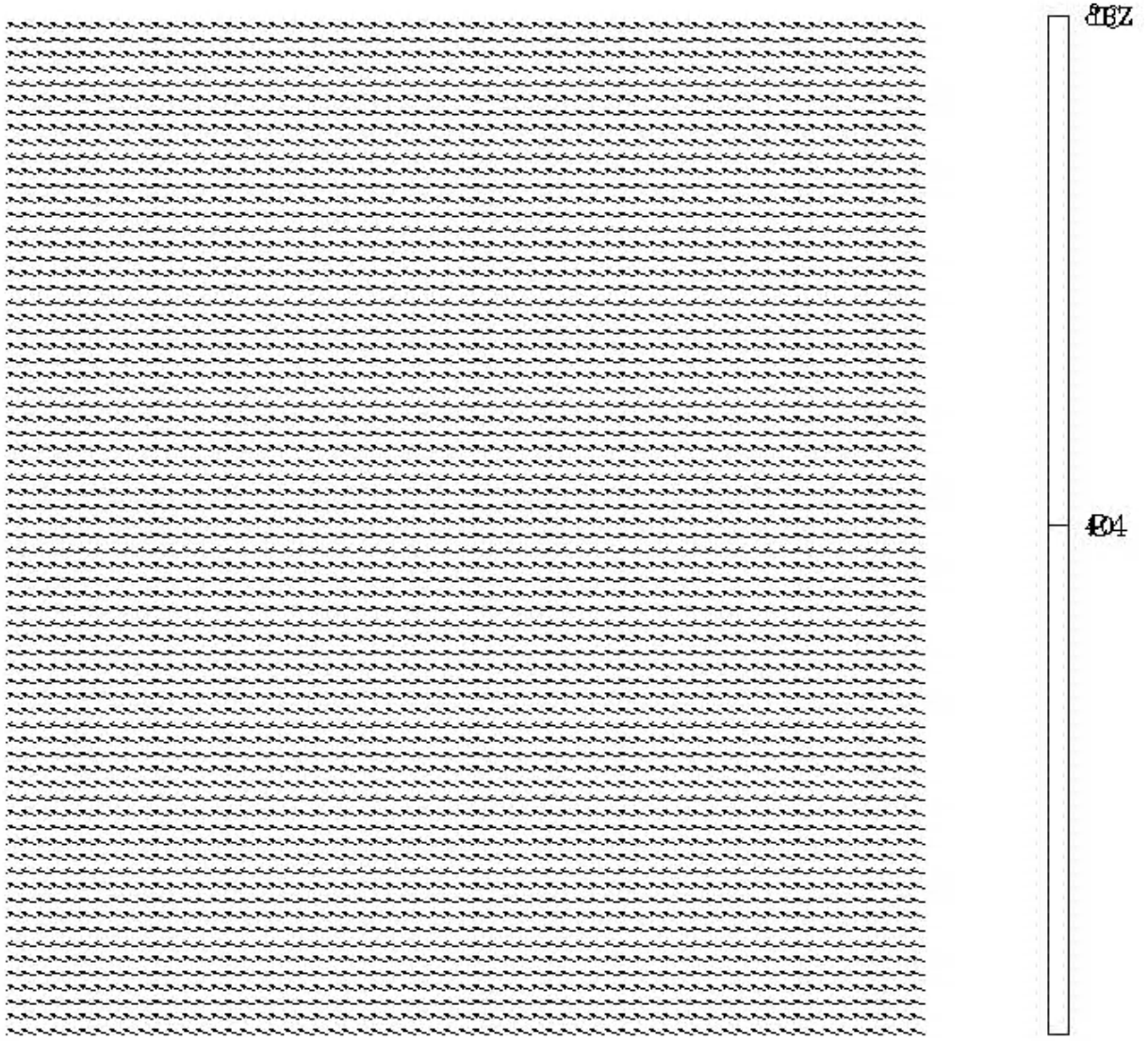


Surface Cold Pool Minimum Temp Perturbation



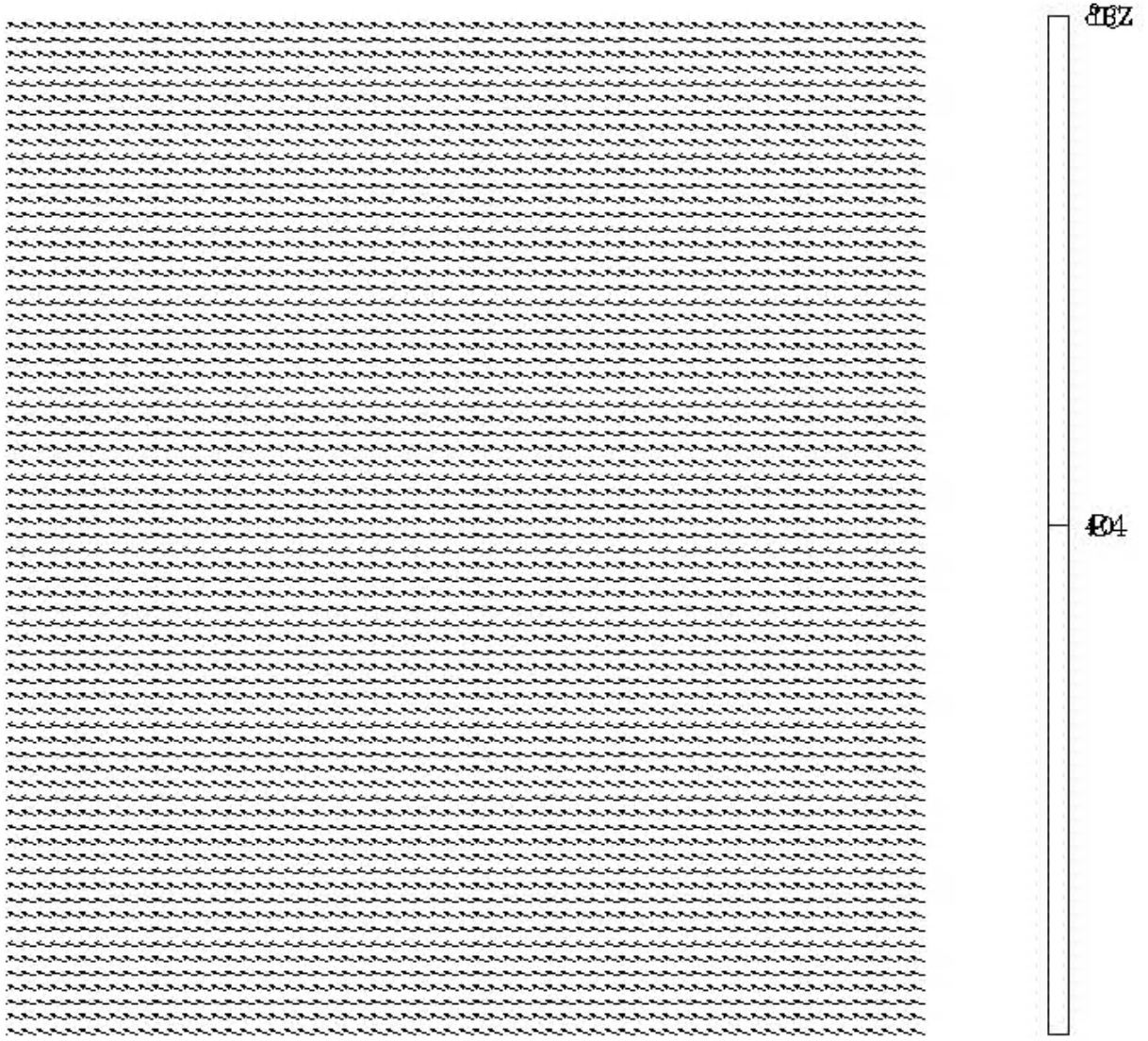

Total Rainfall
(mm)
400
350
300
250
200
150
100
50
0
1
14
27
40
53
66
79
92
105
118
131
144
157
170
183
196
209
222
235
248
261
274
287
300
Time (min)
Morrison3.3H
Milbrand-Yau3.3
Thompson3.3
Grid Points with Rainfall > 25 mm at Sfc
Grid Points
8000
7000
6000
5000
4000
3000
2000
1000
0
1
17
33
49
65
81
97
113
129
145
161
177
193
209
225
241
257
273
289
Time (min)
Morrison3.3H
Milbrandt-Yau3.3
Thompson3.3

Dataset: WRF RIP: Storm Interaction Fcst: 0.00 h
Surface temperature (*C)
Vertical velocity at height = 6.00 km
Horizontal wind vectors at height = 0.00 km



MAXIMUM VECTOR: 15.3 m s^{-1}
CONTOURS: UNITS=cm s^{-1} LOW= 1000.0 HIGH= 1000.0 INTERVAL= 1.0000
Model Info: V3.3 No Cu No PBL Thompson No SFC 540 m, 89 levels, 2 sec
LW: none SW: none DIFF: full KM: 3D Smagor

Dataset: WRF RIP: Storm Interaction Fcst: 0.00 h
Surface temperature (*C)
Vertical velocity at height = 6.00 km
Horizontal wind vectors at height = 0.00 km



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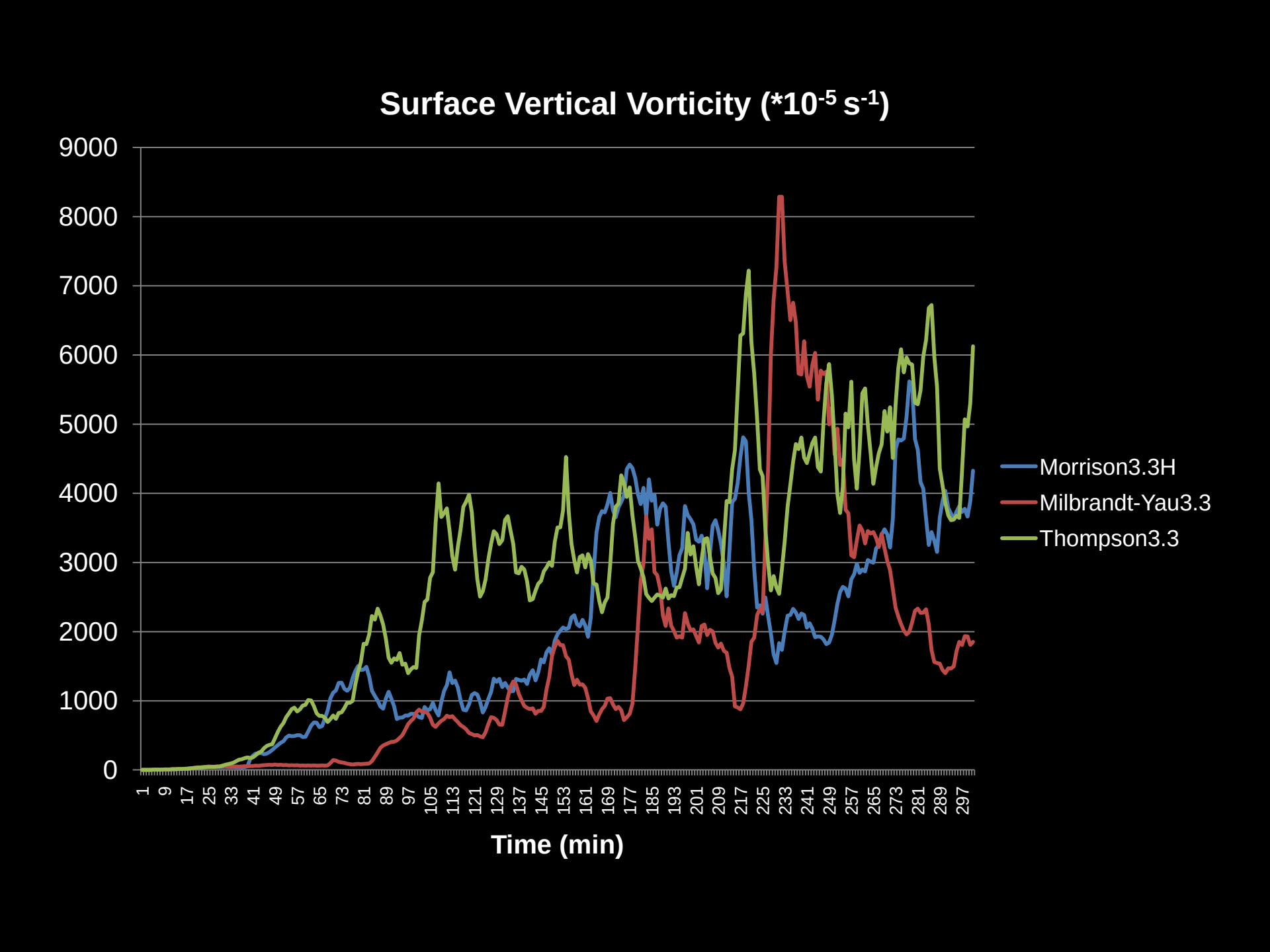
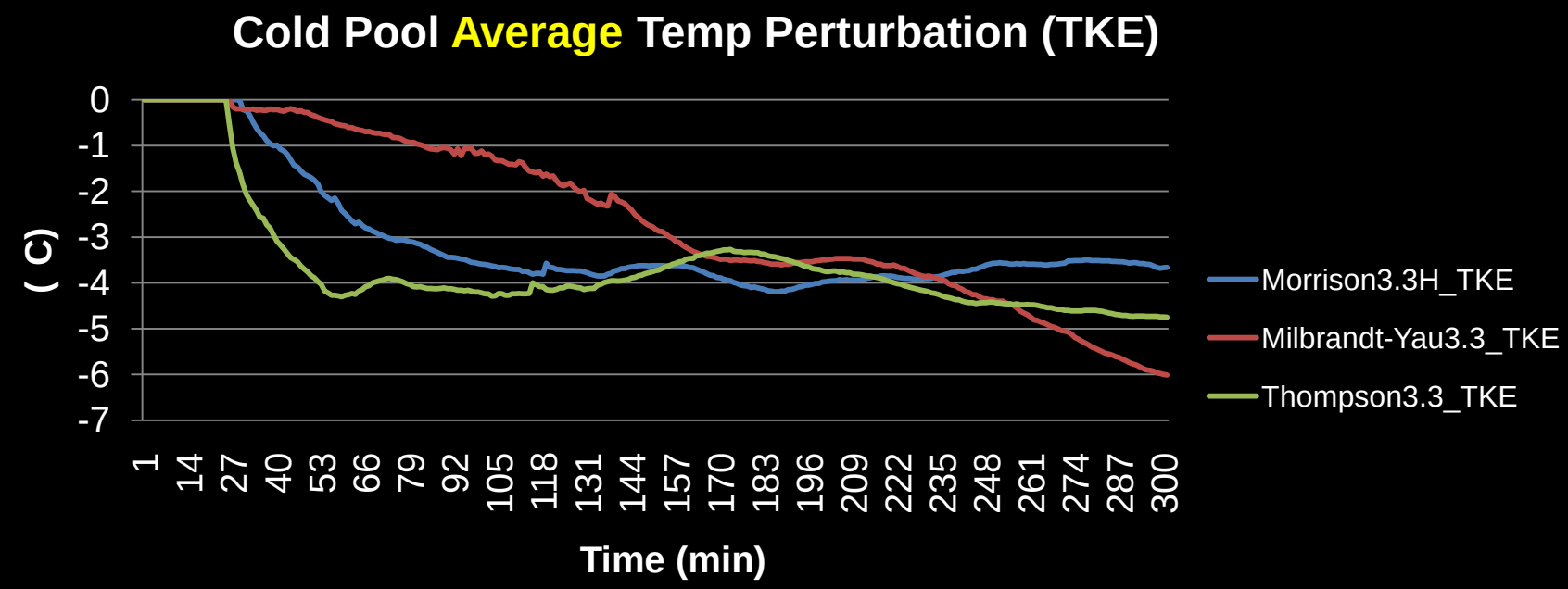
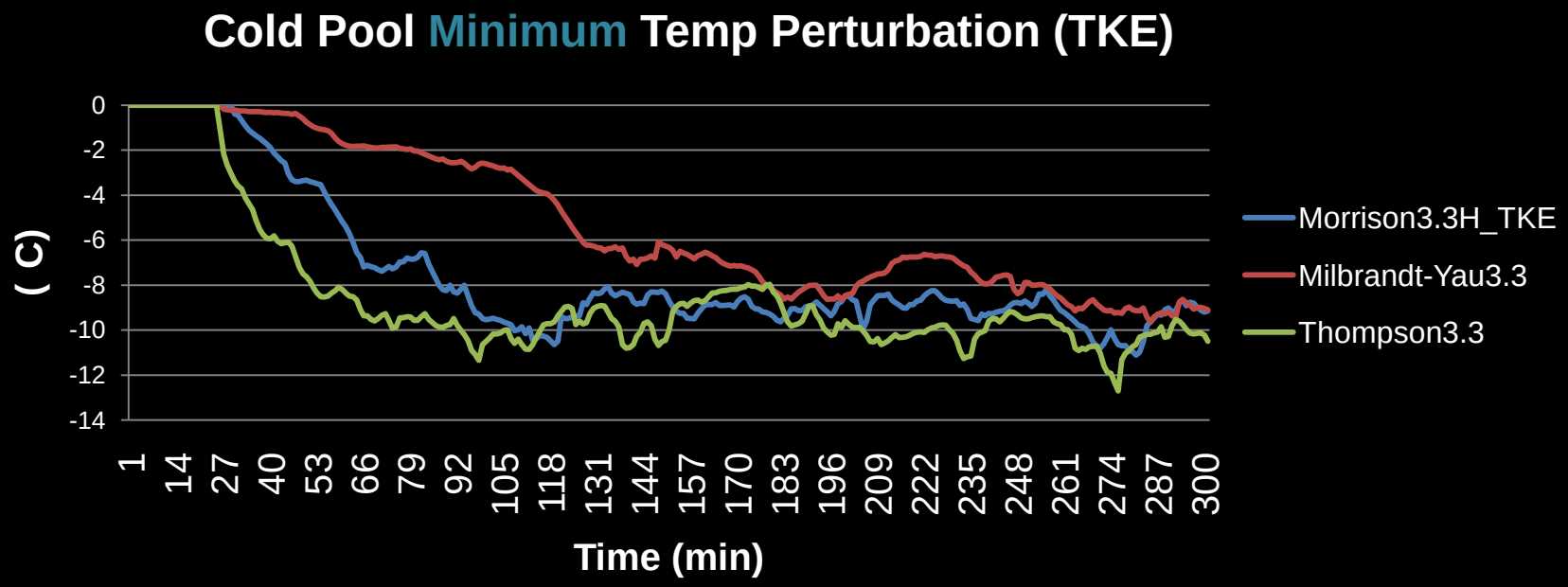
Model Info: V3.3 No Cu No PBL Thompson No SFC 540 m, 89 levels, 2 sec
LW: none SW: none DIFF: full KM: 3D Smagor

Summary

- Evaluated Morrison3.3H, Milbrandt-Yau3.3, and Thompson3.3 microphysics schemes for high-resolution numerical study of favorable supercell interaction
- MorrisonH3.3 sustains strongest and most long-lived hook echo
- MorrisonH3.3 and Thompson3.3 exhibit cold pools with similar intensity and coverage early on, but MorrisonH3.3 sustains a weak cold pool over a larger area of the domain for the entire simulation
- On average, M-Y3.3 produced the warmest cold pool throughout 4 hrs and 40 min of the simulation, and showed the warmest minimum temperatures
- Cold pool behavior is unsteady and “pulse”-like for all three schemes
- High rainfall totals with Thompson3.3 (~12 inches)
- TKE diffusion option produces more noise than simulations using Smagorinsky 3-D diffusion


Surface Vertical Vorticity (*10-5 s-1)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1
9
17
25
33
41
49
57
65
73
81
89
97
105
113
121
129
137
145
153
161
169
177
185
193
201
209
217
225
233
241
249
257
265
273
281
289
297
Time (min)
Morrison3.3H
Milbrandt-Yau3.3
Thompson3.3


Cold Pool Average Temp Perturbation (TKE)
0
-1
-2
-3
-4
-5
-6
-7
(C)
1
14
27
40
53
66
79
92
105
118
131
144
157
170
183
196
209
222
235
248
261
274
287
300
Time (min)
Morrison3.3H_TKE
Milbrandt-Yau3.3_TKE
Thompson3.3_TKE


Cold Pool Minimum Temp Perturbation (TKE)
0
-2
-4
-6
-8
-10
-12
-14
(C)
1
14
27
40
53
66
79
92
105
118
131
144
157
170
183
196
209
222
235
248
261
274
287
300
Time (min)
Morrison3.3H_TKE
Milbrandt-Yau3.3
Thompson3.3