Precipitation from Mesoscale Convective Clouds: TRMM Observations and GCMs

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I. GCM studies of the role of mesoscale stratiform clouds in the general circulation.

- A. Heat source.
- B. Moisture sink.
- C. Mass fluxes and tracer transport.
- D. Size distribution of convective cloud systems.

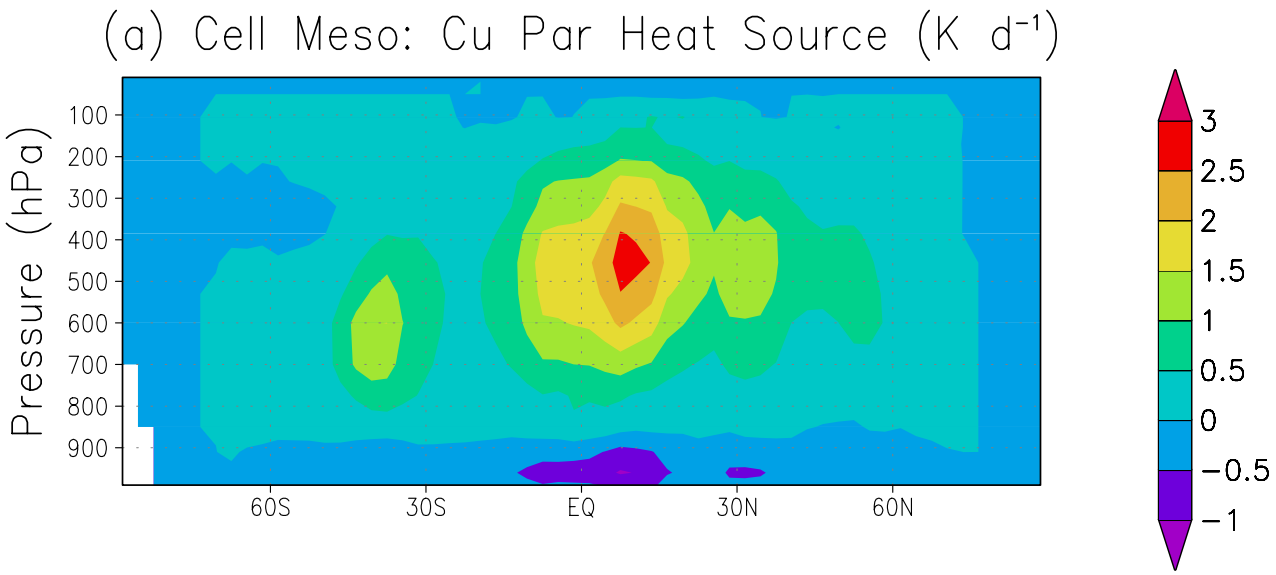
II. Satellite observations of size distribution of convective cloud systems.

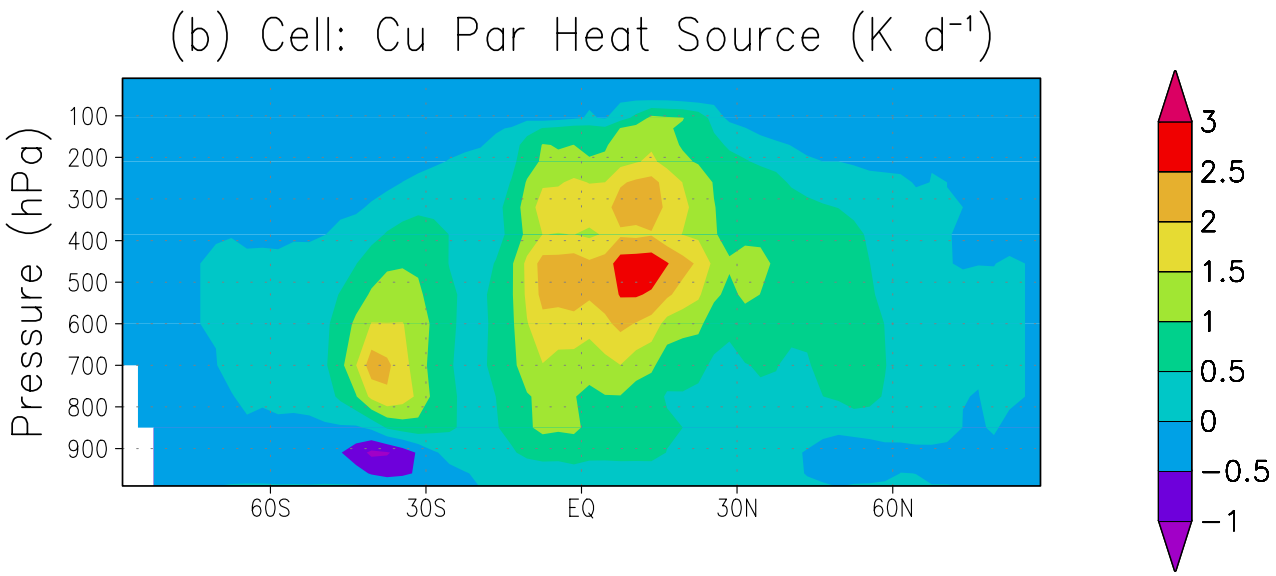
III. GCM studies of the dependence of mesoscale stratiform cloud systems on vertical velocities in cumulus convection.

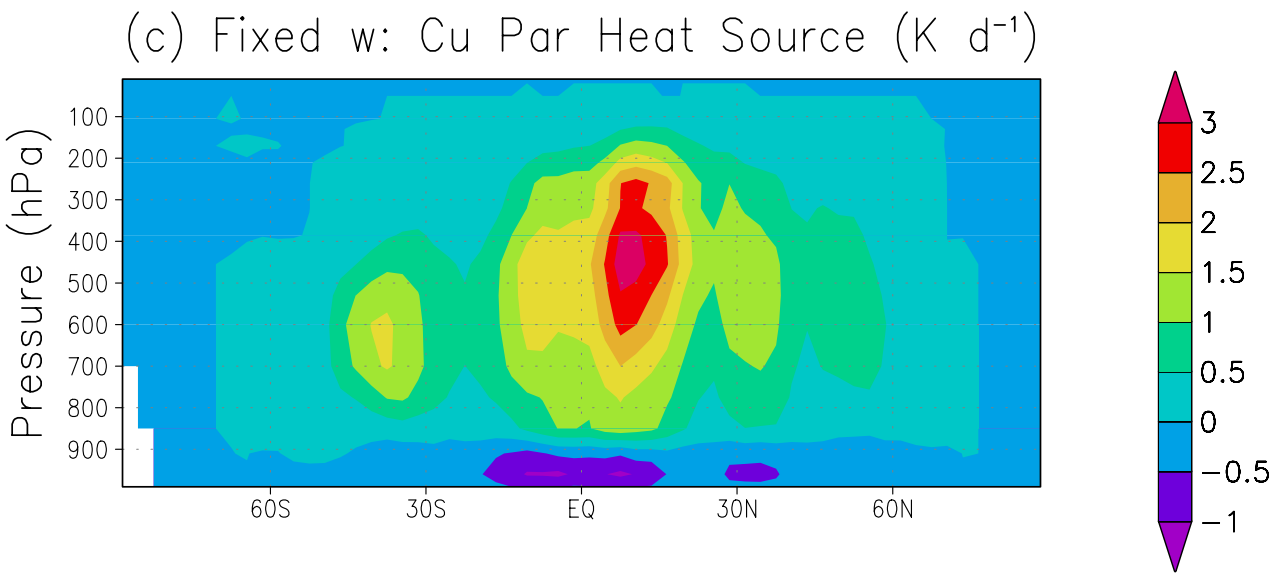
IV. TRMM observations of convective and stratiform precipitation and comparison with GCM results.

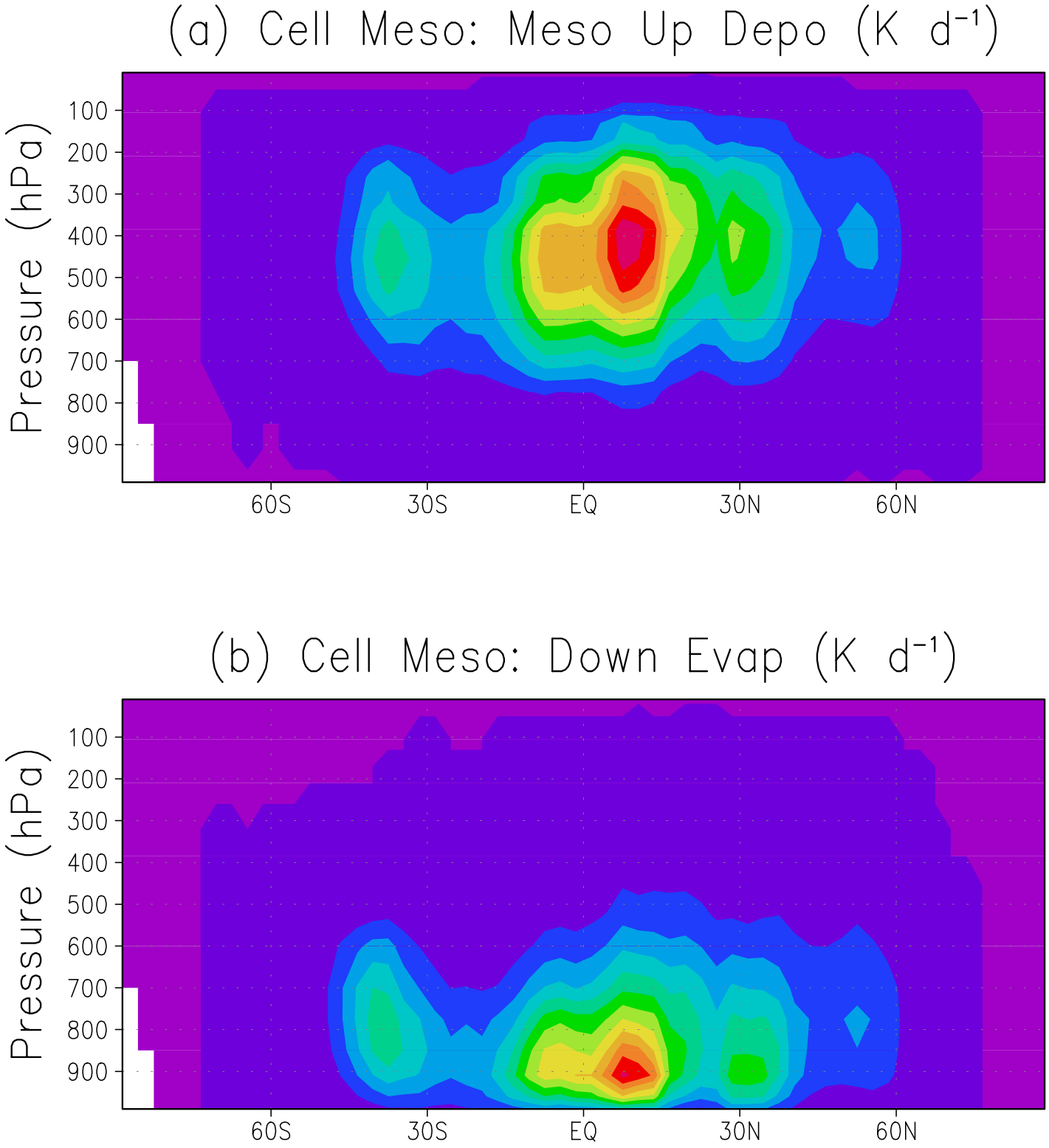
Geophysical
Fluid
Dynamics
Laboratory

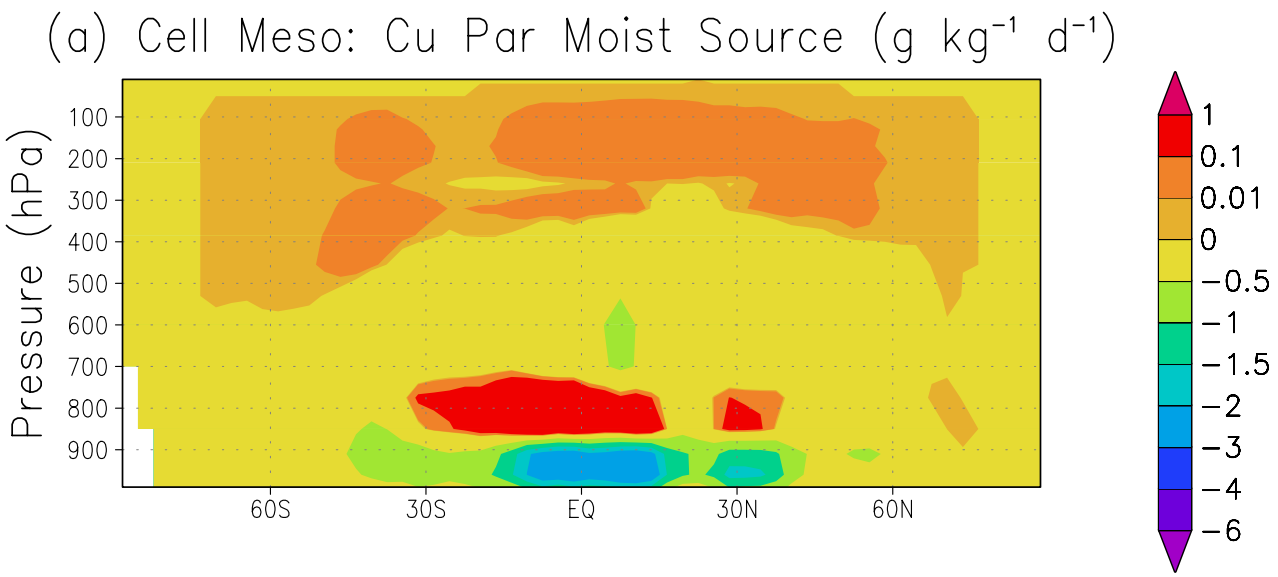
Princeton, New Jersey

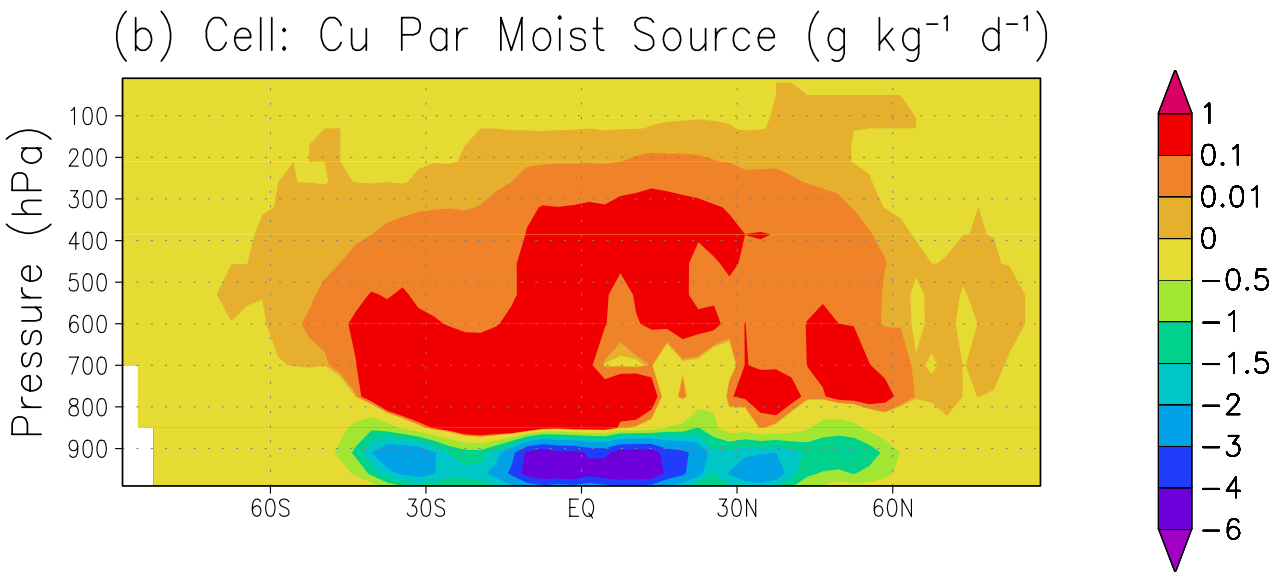

(a) Cell Meso: Cu Par Heat Source (K d⁻¹)
Pressure (hPa)
100
200
300
400
500
600
700
800
900
60S
30S
EQ
30N
60N
3
2.5
2
1.5
1
0.5
0
−0.5
−1

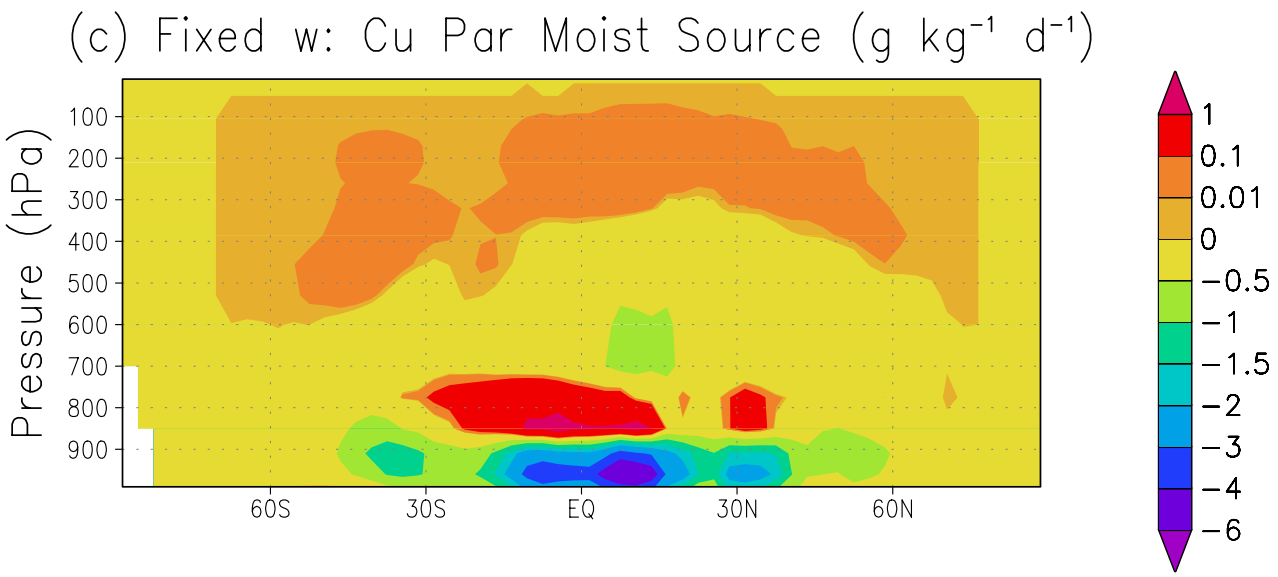

(b) Cell: Cu Par Heat Source (K d⁻¹)
Pressure (hPa)
100
200
300
400
500
600
700
800
900
60S
30S
EQ
30N
60N
3
2.5
2
1.5
1
0.5
0
−0.5
−1

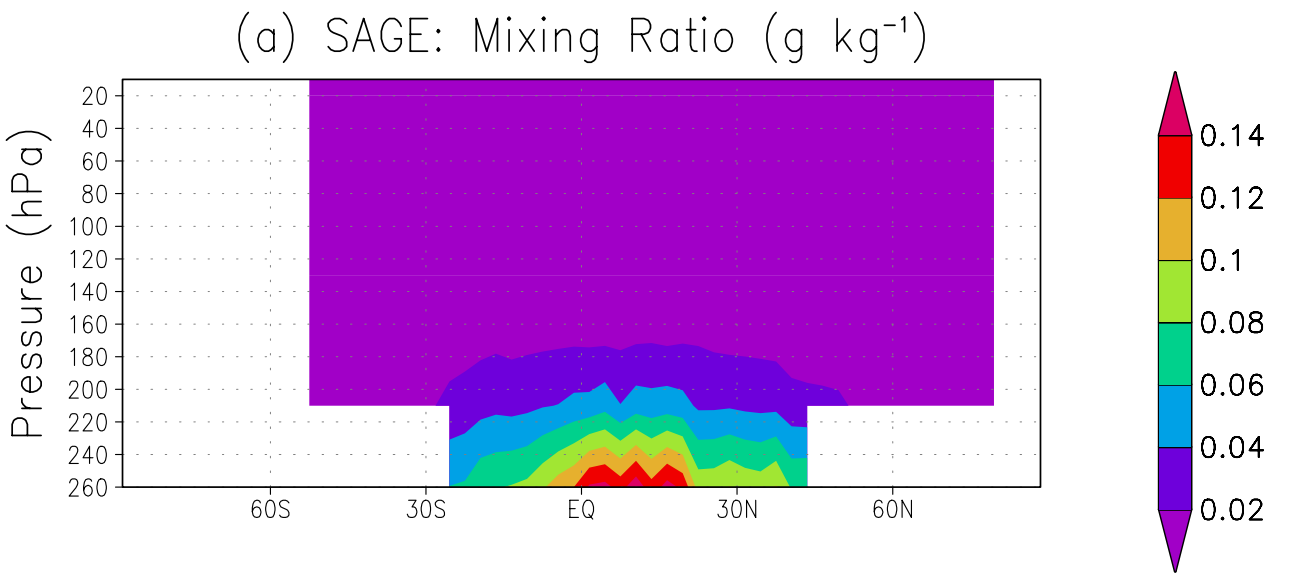

(c) Fixed w: Cu Par Heat Source (K d⁻¹)
Pressure (hPa)
100
200
300
400
500
600
700
800
900
60S
30S
EQ
30N
60N
3
2.5
2
1.5
1
0.5
0
−0.5
−1

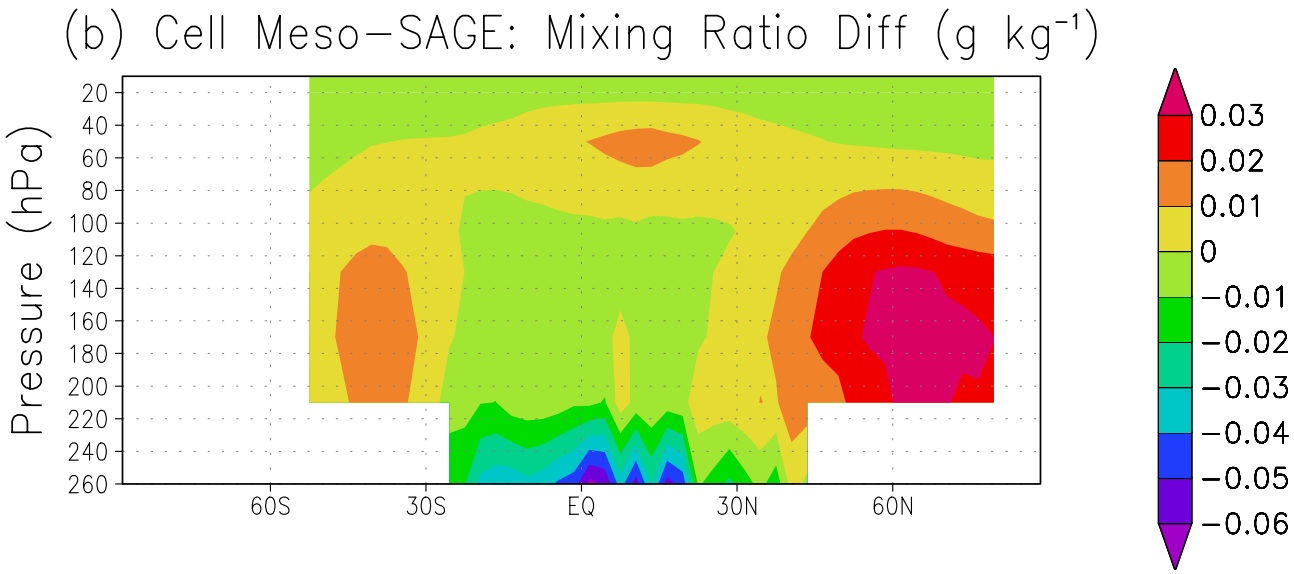

(a) Cell Meso: Meso Up Depo (K d^{-1})
Pressure (hPa)
100
200
300
400
500
600
700
800
900
60S
30S
EQ
30N
60N
(b) Cell Meso: Down Evap (K d^{-1})
Pressure (hPa)
100
200
300
400
500
600
700
800
900
60S
30S
EQ
30N
60N

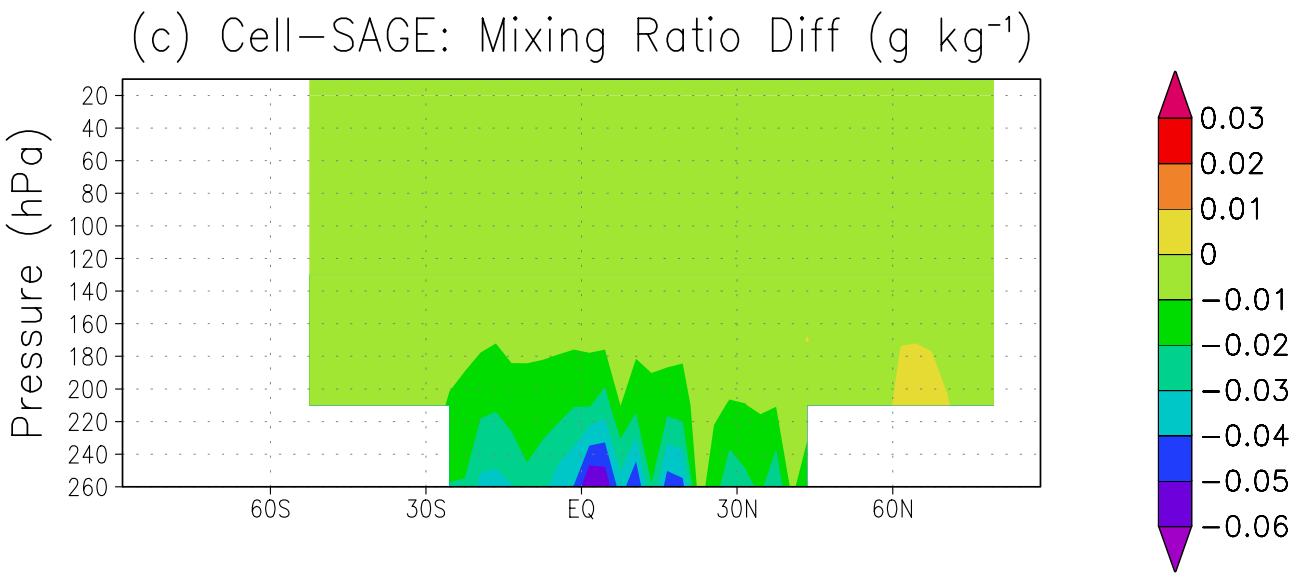

(a) Cell Meso: Cu Par Moist Source (g kg⁻¹ d⁻¹)
Pressure (hPa)
100
200
300
400
500
600
700
800
900
60S
30S
EQ
30N
60N
1
0.1
0.01
0
−0.5
−1
−1.5
−2
−3
−4
−6

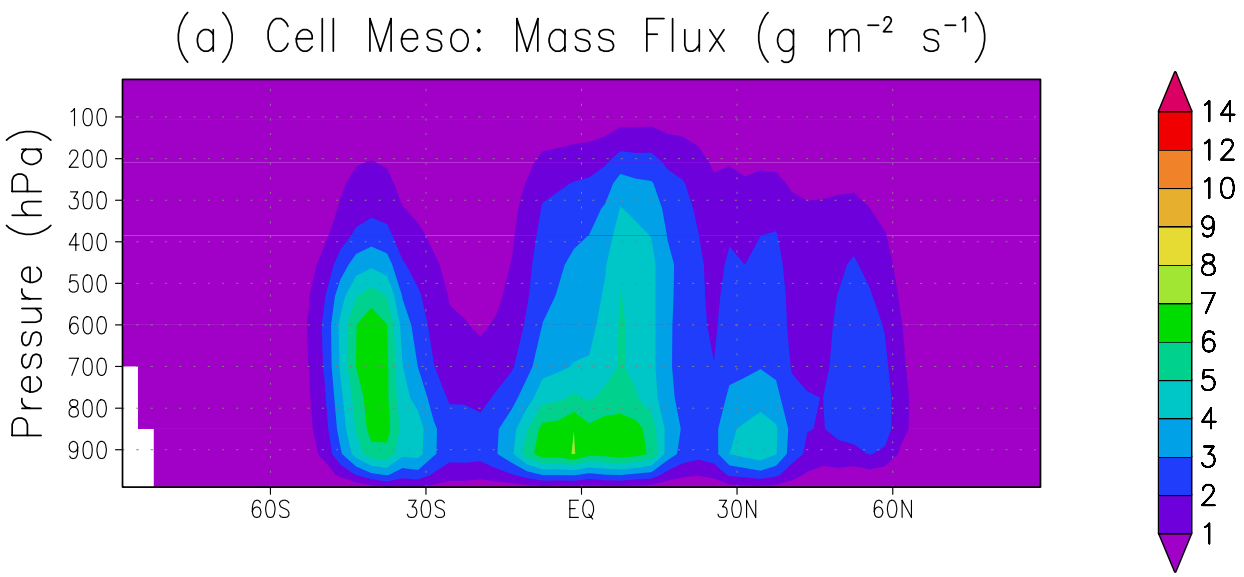

(b) Cell: Cu Par Moist Source (g kg⁻¹ d⁻¹)
Pressure (hPa)
100
200
300
400
500
600
700
800
900
60S
30S
EQ
30N
60N
1
0.1
0.01
0
−0.5
−1
−1.5
−2
−3
−4
−6

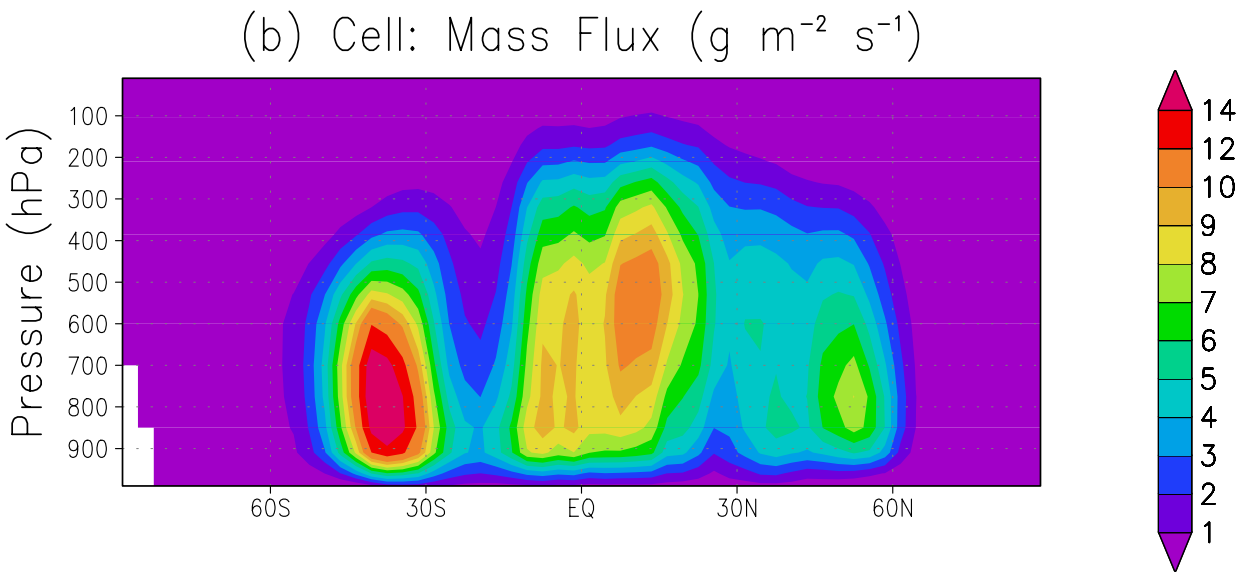

(c) Fixed w: Cu Par Moist Source (g kg⁻¹ d⁻¹)
Pressure (hPa)
100
200
300
400
500
600
700
800
900
60S
30S
EQ
30N
60N
1
0.1
0.01
0
−0.5
−1
−1.5
−2
−3
−4
−6

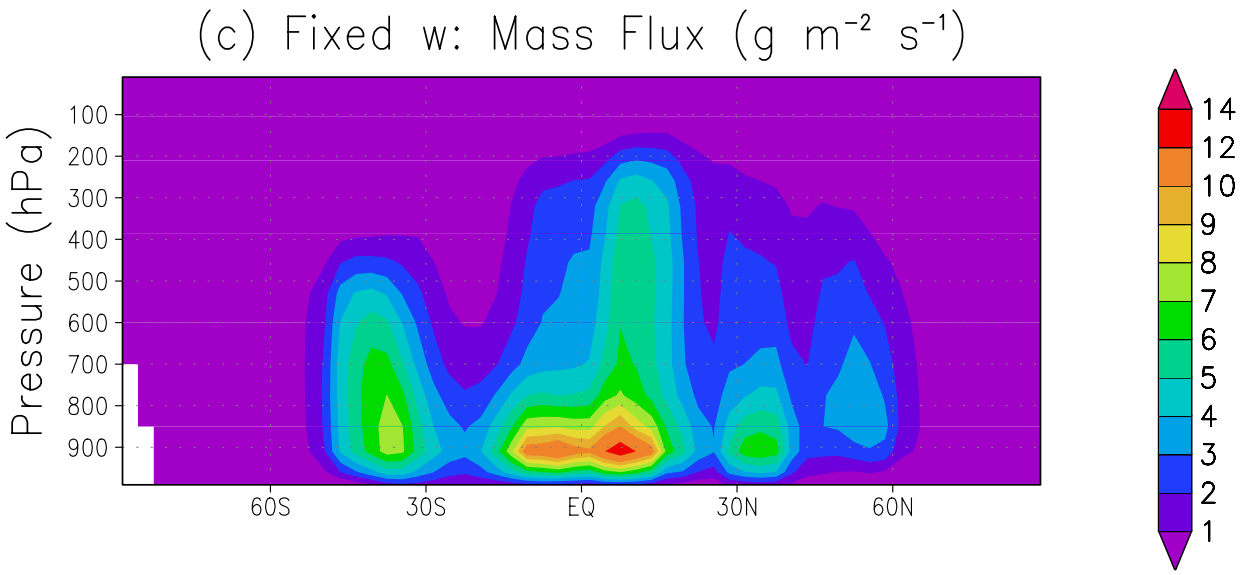

(a) SAGE: Mixing Ratio (g kg⁻¹)
Pressure (hPa)
20
40
60
80
100
120
140
160
180
200
220
240
260
60S
30S
EQ
30N
60N
0.14
0.12
0.1
0.08
0.06
0.04
0.02

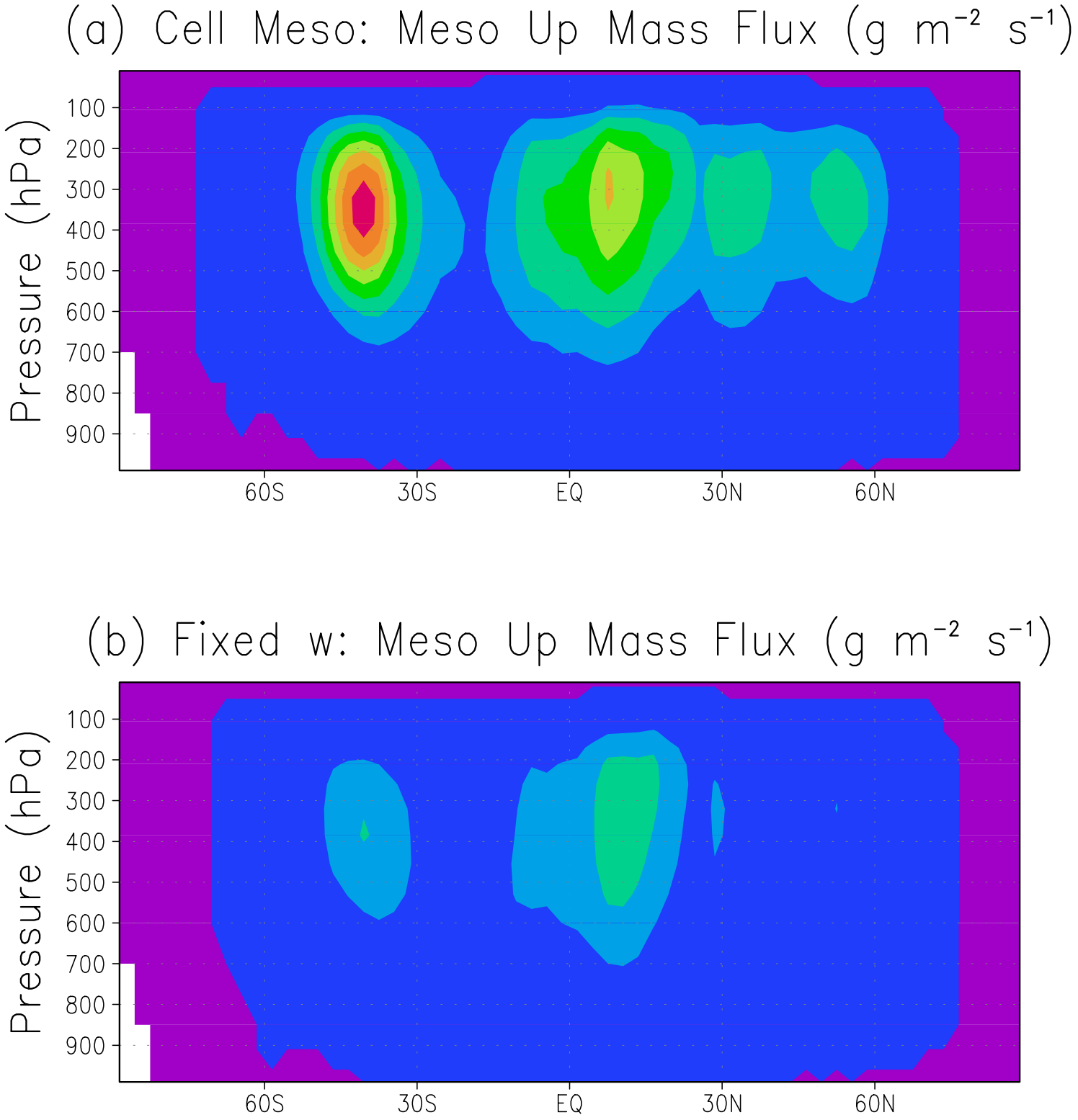

(b) Cell Meso−SAGE: Mixing Ratio Diff (g kg⁻¹)
Pressure (hPa)
20
40
60
80
100
120
140
160
180
200
220
240
260
60S
30S
EQ
30N
60N
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
−0.04
−0.05
−0.06

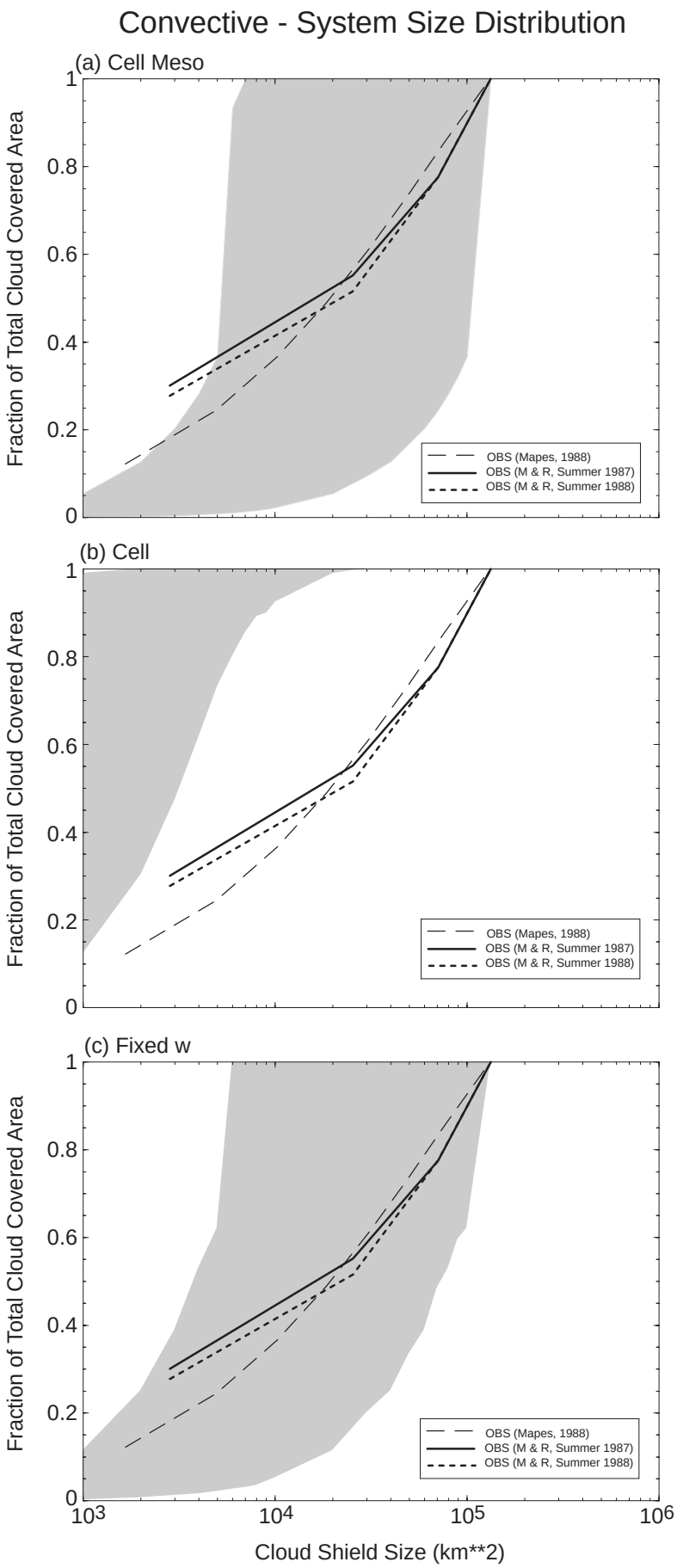

(c) Cell−SAGE: Mixing Ratio Diff (g kg⁻¹)
Pressure (hPa)
20
40
60
80
100
120
140
160
180
200
220
240
260
60S
30S
EQ
30N
60N
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
−0.04
−0.05
−0.06

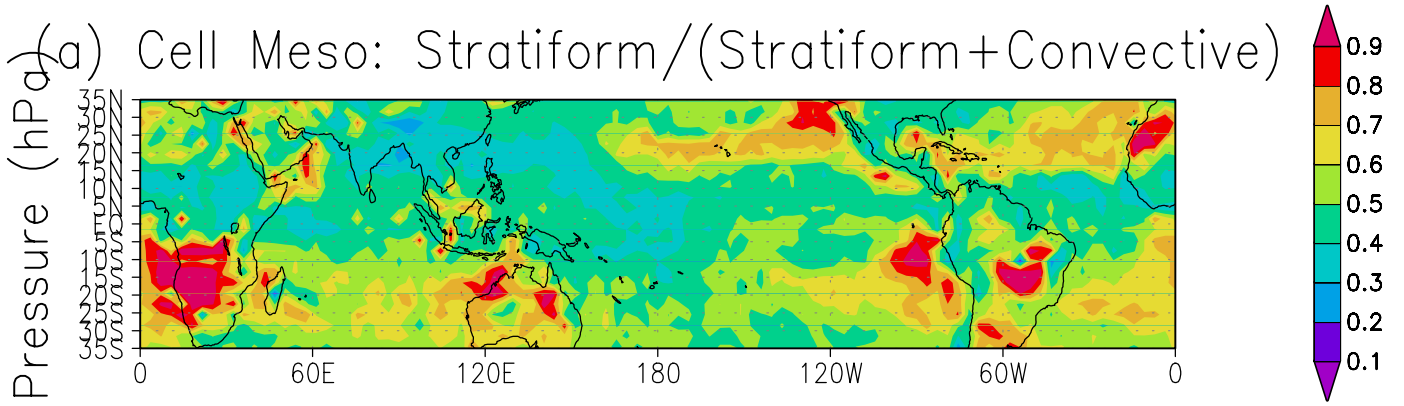

(a) Cell Meso: Mass Flux (g m^{-2} s^{-1})
Pressure (hPa)
100
200
300
400
500
600
700
800
900
60S
30S
EQ
30N
60N
14
12
10
9
8
7
6
5
4
3
2
1

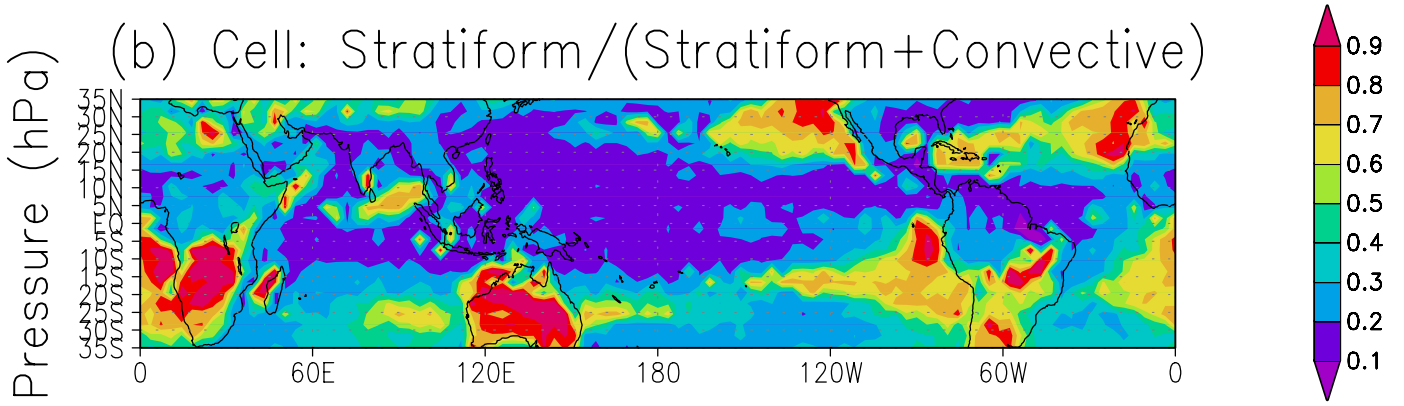

(b) Cell: Mass Flux (g m^{-2} s^{-1})
Pressure (hPa)
100
200
300
400
500
600
700
800
900
60S
30S
EQ
30N
60N
14
12
10
9
8
7
6
5
4
3
2
1

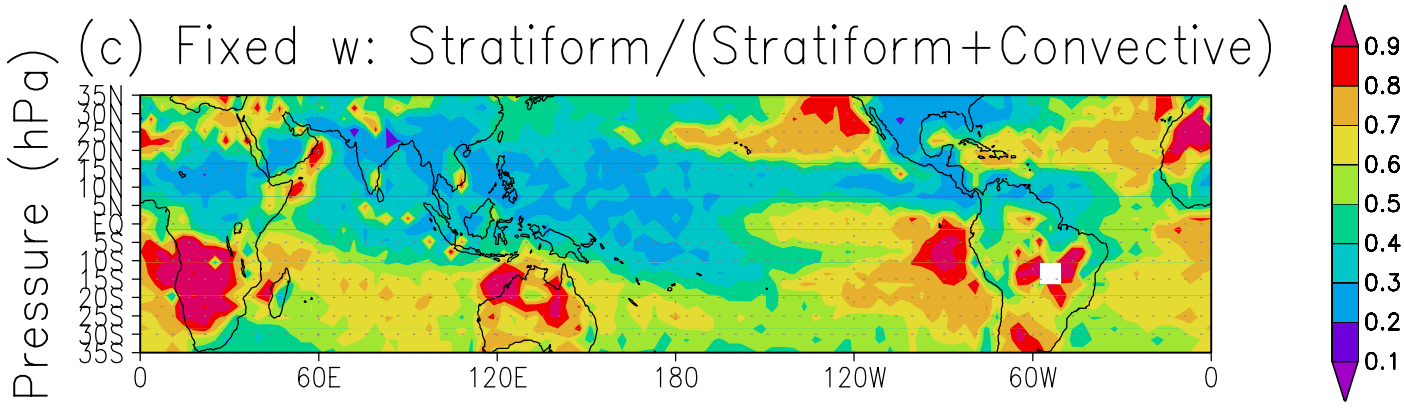

(c) Fixed w: Mass Flux (g m^{-2} s^{-1})
Pressure (hPa)
100
200
300
400
500
600
700
800
900
60S
30S
EQ
30N
60N
14
12
10
9
8
7
6
5
4
3
2
1

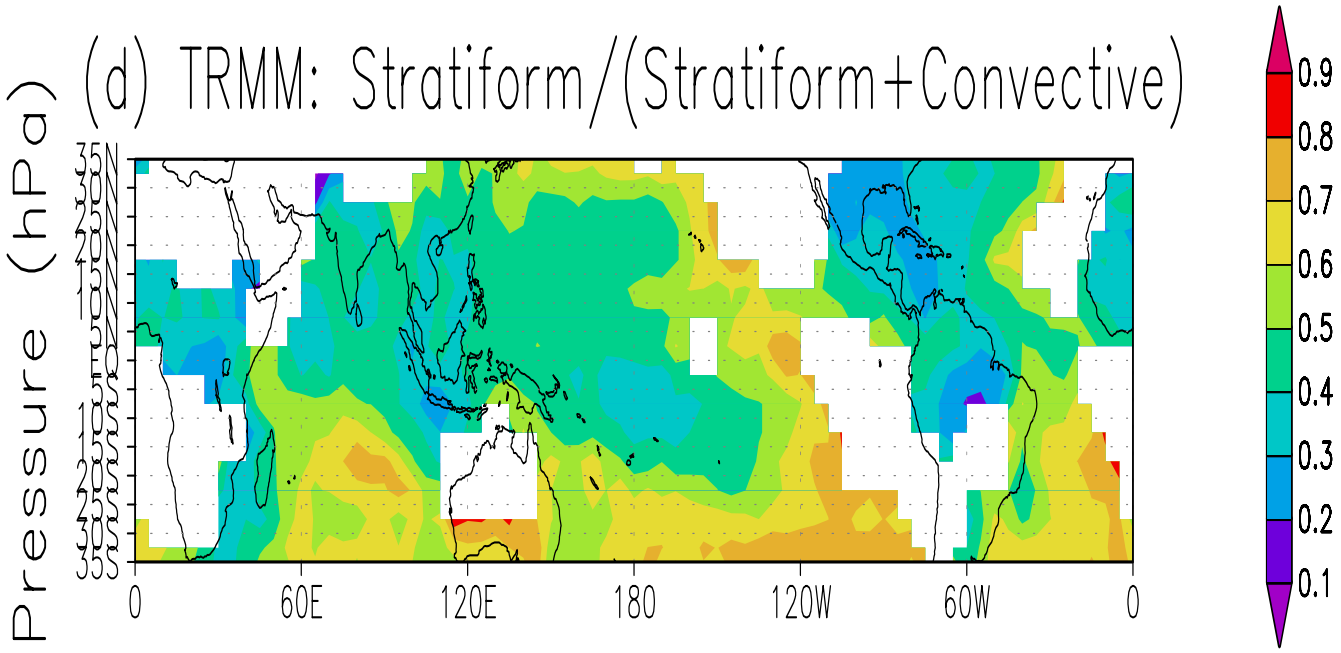

(a) Cell Meso: Meso Up Mass Flux (g m^{-2} s^{-1})
Pressure (hPa)
100
200
300
400
500
600
700
800
900
60S
30S
EQ
30N
60N
(b) Fixed w: Meso Up Mass Flux (g m^{-2} s^{-1})
Pressure (hPa)
100
200
300
400
500
600
700
800
900
60S
30S
EQ
30N
60N


Convective - System Size Distribution
(a) Cell Meso
(b) Cell
(c) Fixed w
Fraction of Total Cloud Covered Area
0
0.2
0.4
0.6
0.8
1
OBS (Mapes, 1988)
OBS (M & R, Summer 1987)
OBS (M & R, Summer 1988)
10^3
10^4
10^5
10^6
Cloud Shield Size (km**2)


(a) Cell Meso: Stratiform/(Stratiform+Convective)
Pressure (hPa)
0
60E
120E
180
120W
60W
0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


(b) Cell: Stratiform/(Stratiform+Convective)
Pressure (hPa)
0
60E
120E
180
120W
60W
0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


(c) Fixed w: Stratiform/(Stratiform+Convective)
Pressure (hPa)
0
60E
120E
180
120W
60W
0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


(d) TRMM: Stratiform/(Stratiform+Convective)
Pressure (hPa)
0
60E
120E
180
120W
60W
0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

Mesosocale Clouds Generated by Deep Convection: What Controls their Extent?

I. For condensate, increased precipitation efficiency in deep convective cells can mean less mesoscale cloud coverage.

II. Cell precipitation efficiency increases as transit time spent by parcels in deep convection increases, allowing more time for collection and coalescence.

III. Transit time ~ Cumulus Depth/Cumulus Vertical Velocity

IV. Cumulus Vertical Velocity ~ $\sqrt{2CAPE}$

V. CAPE ~ (Cumulus Depth) ΔT

VI. $\Delta T \sim T(cloud) - \overline{T}$

VII. Transit Time ~ Cumulus Depth/$\sqrt{CAPE}$ ~ $\sqrt{\frac{CumulusDepth}{\Delta T}}$

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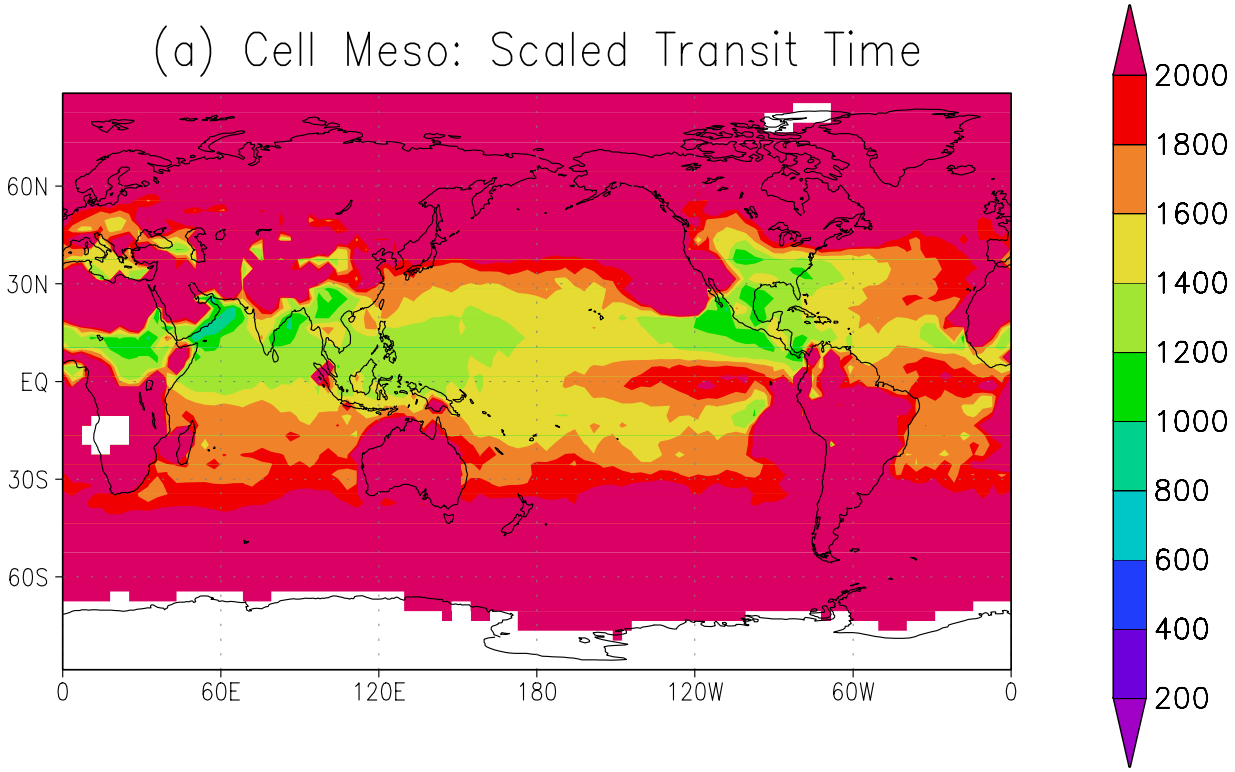
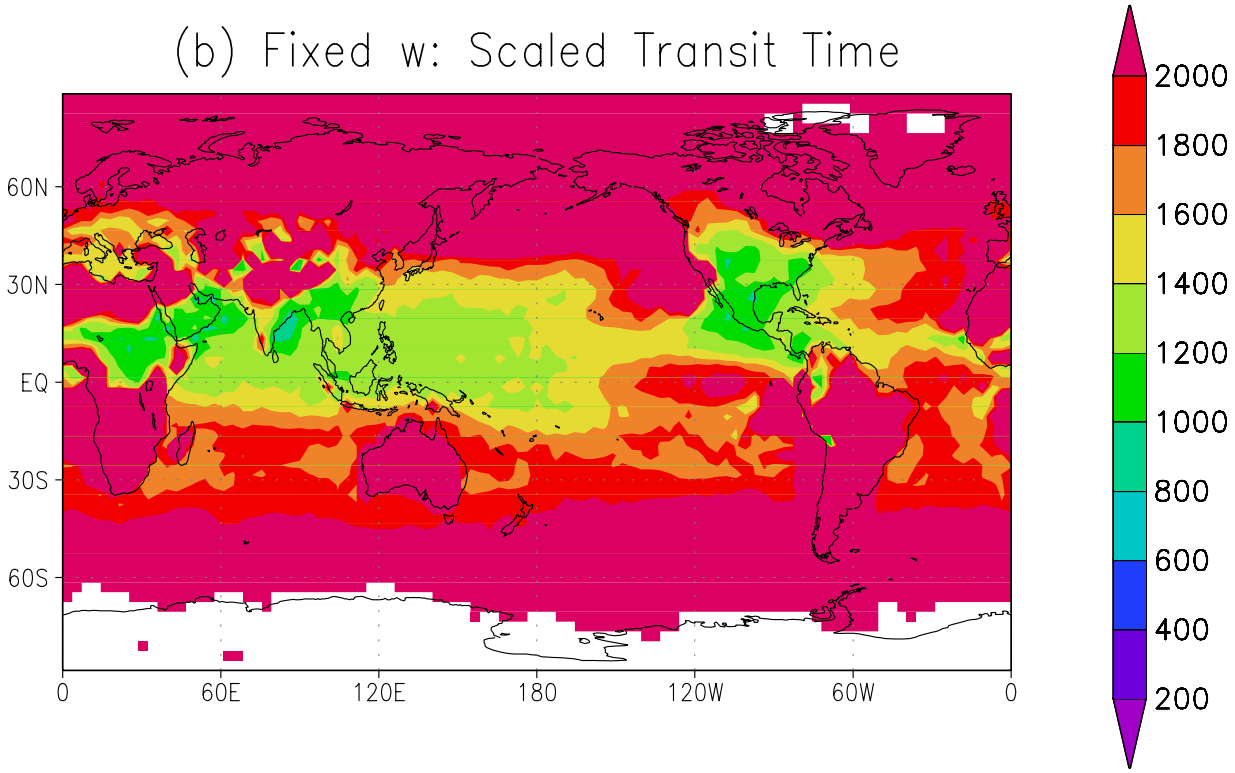

(a) Cell Meso: Scaled Transit Time
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0
2000
1800
1600
1400
1200
1000
800
600
400
200


(b) Fixed w: Scaled Transit Time
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0
2000
1800
1600
1400
1200
1000
800
600
400
200