Boundary-layer Clouds in a Multi-scale Modeling Framework (MMF)

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Cloud resolving model (CRM) description

TOC model classifications

- FP model: all third moments predicted
- MP model: only third moment of w predicted
- PP model: important third moments predicted
- Why PP model?
  - more useful information than MP model
  - faster than FP model
  - avoid Liquid Water Oscillation
  - internally consistent

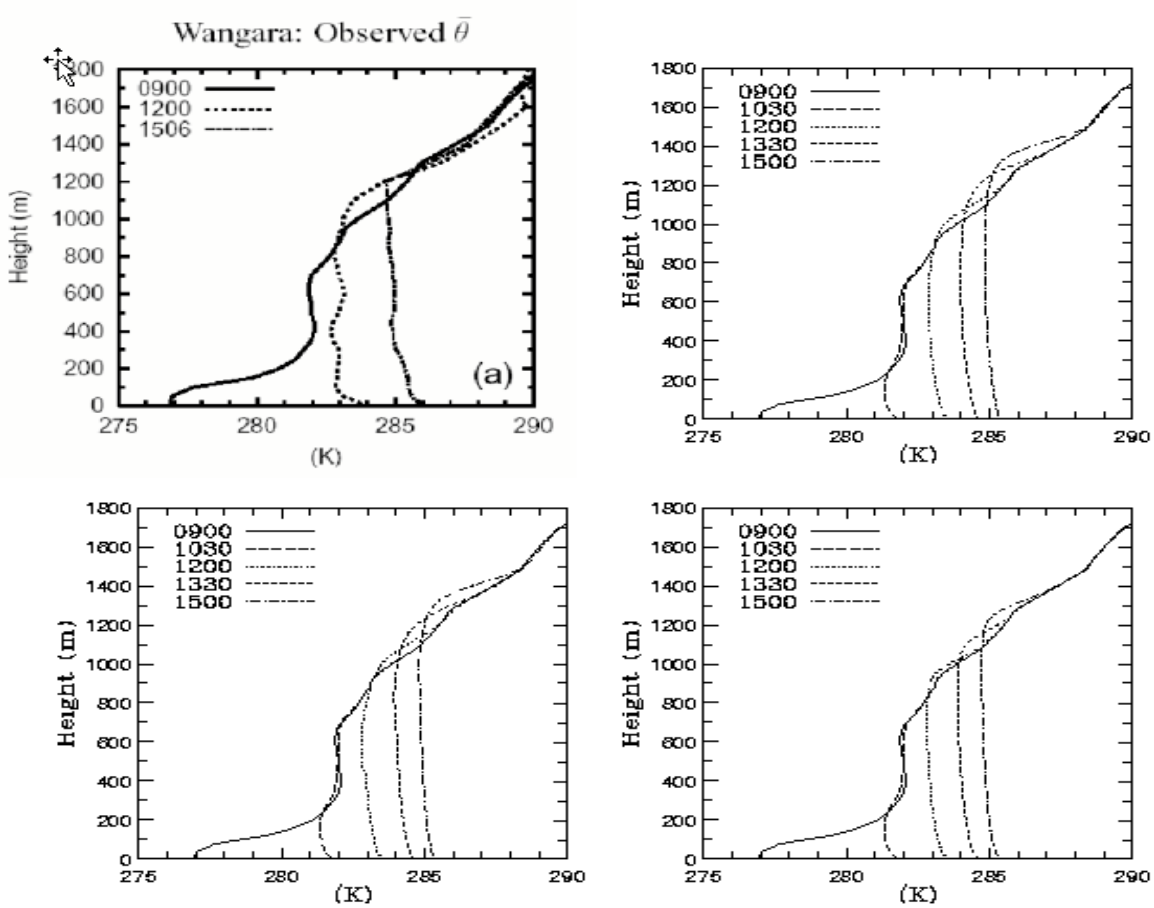
Model description (PP)

- Double Gaussian-based third-order closure
- Turbulence condensation scheme
- Realistic buoyancy calculation
- All moments are based on the same PDF to ensure consistency
- Three third-order moments are predicted to save computation time

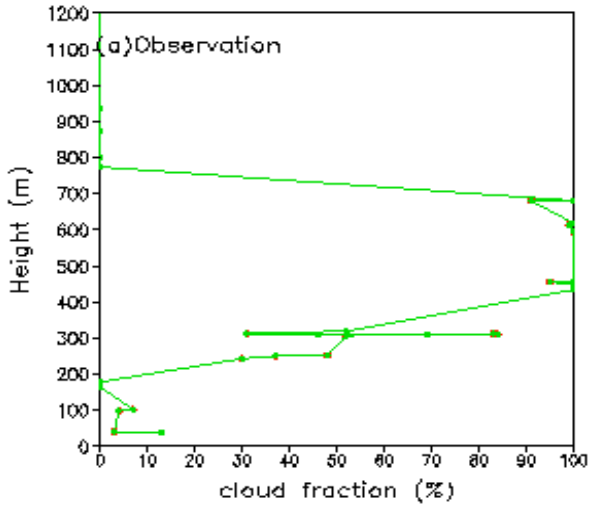
Comparison of computational costs

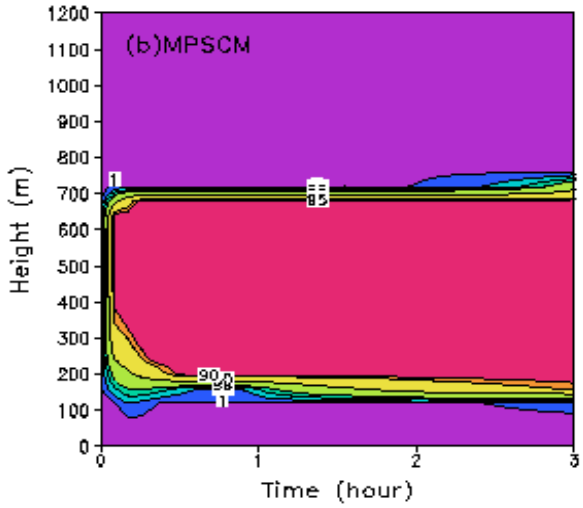
Time	Wangara	ASTEX	BOMEX	ARM	ATEX
MP (s)	52	13	57	183	79
PP (s)	64	13	66	207	89
FP (s)	112	29	128	446	177

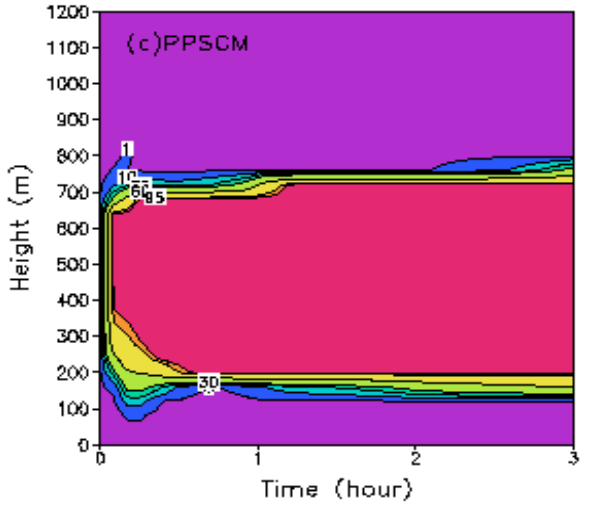
Clear convective boundary layer

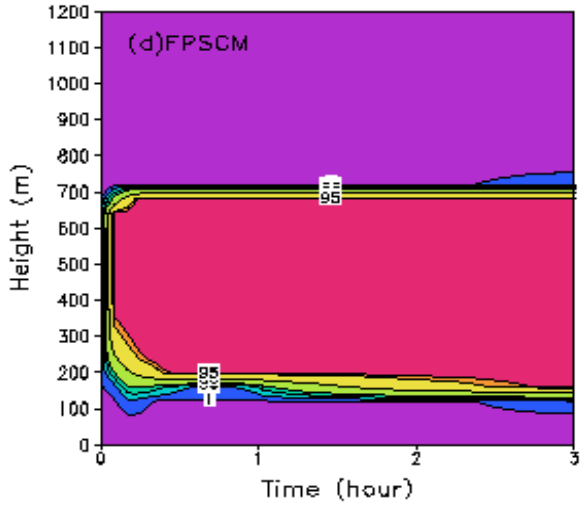


Stratocumulus (ASTEX)

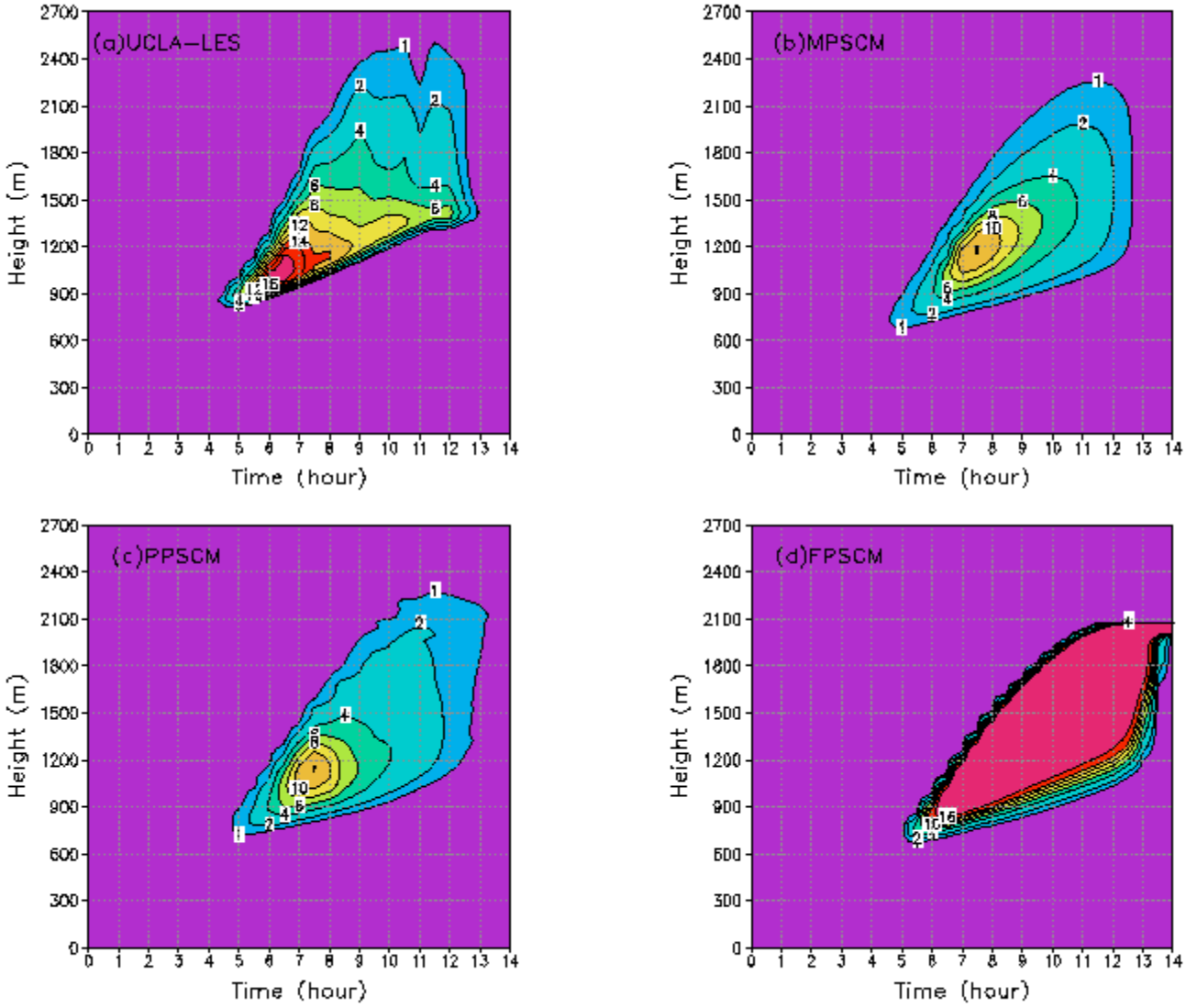




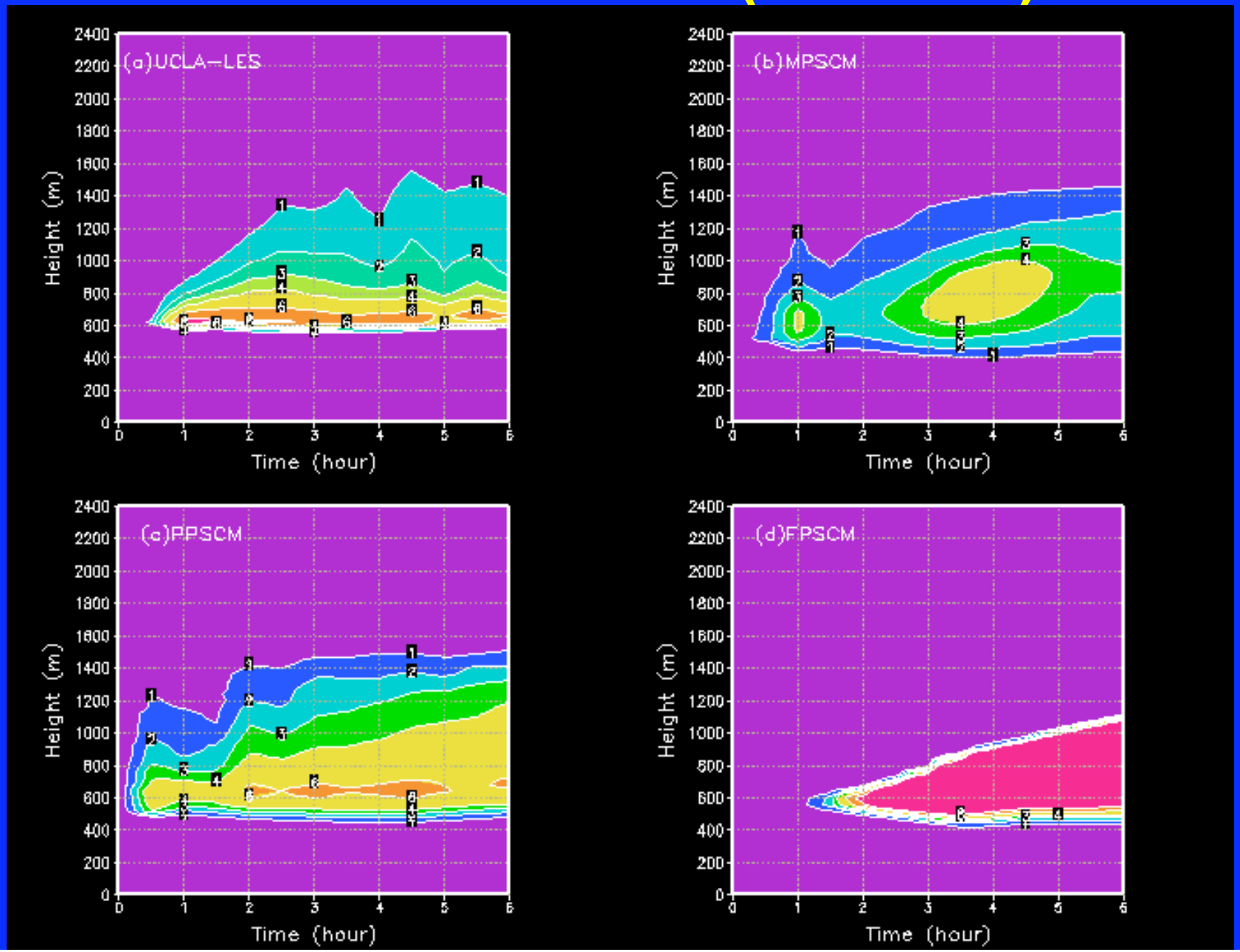




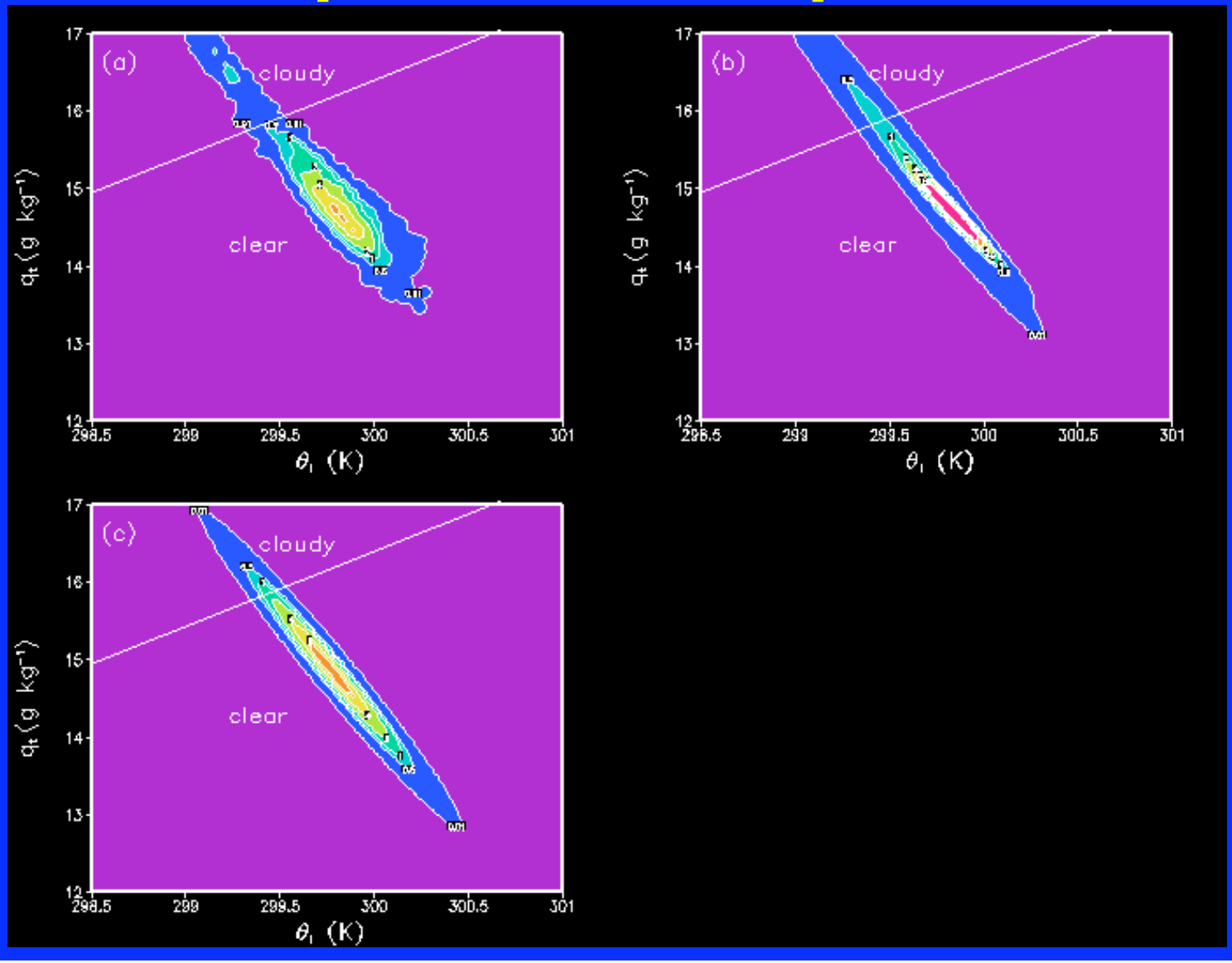
Continental shallow cumuli (ARM)



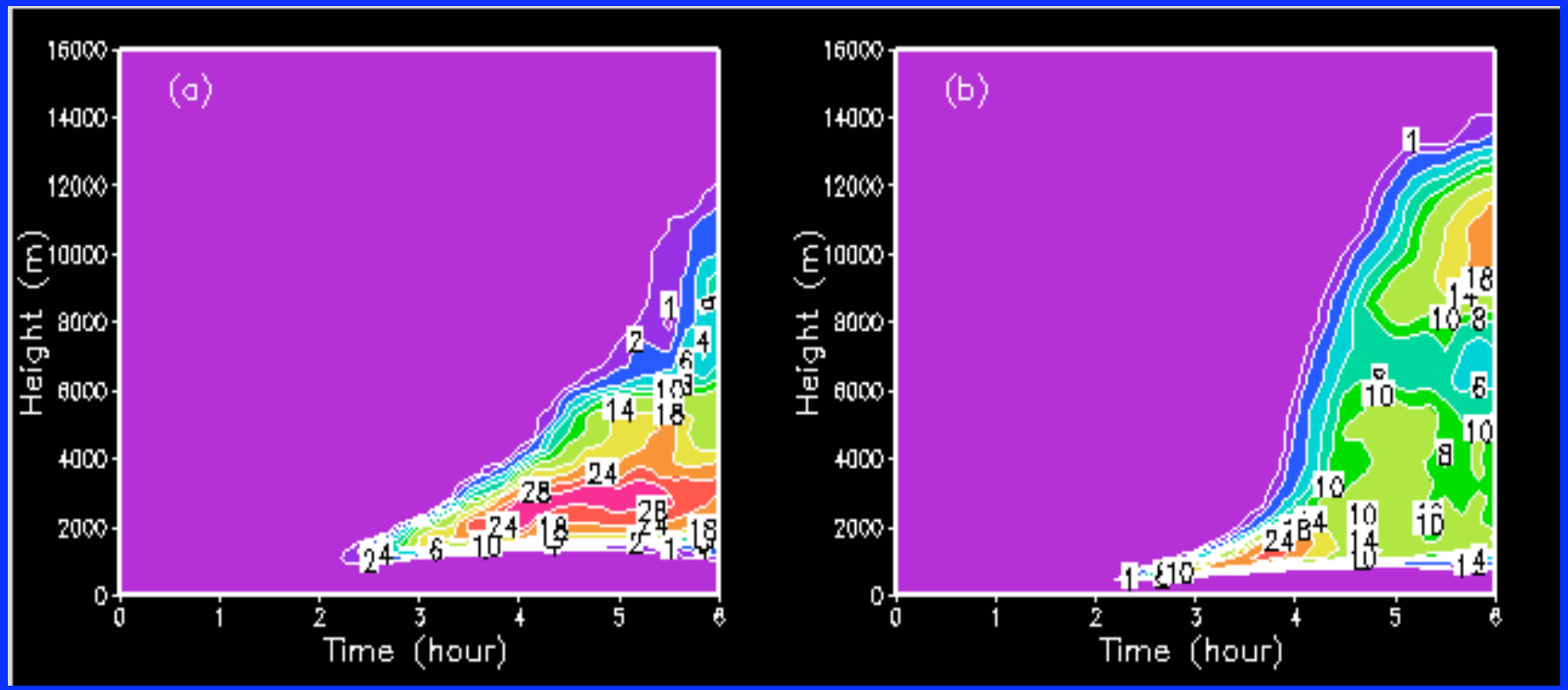
Shallow cumuli (BOMEX)



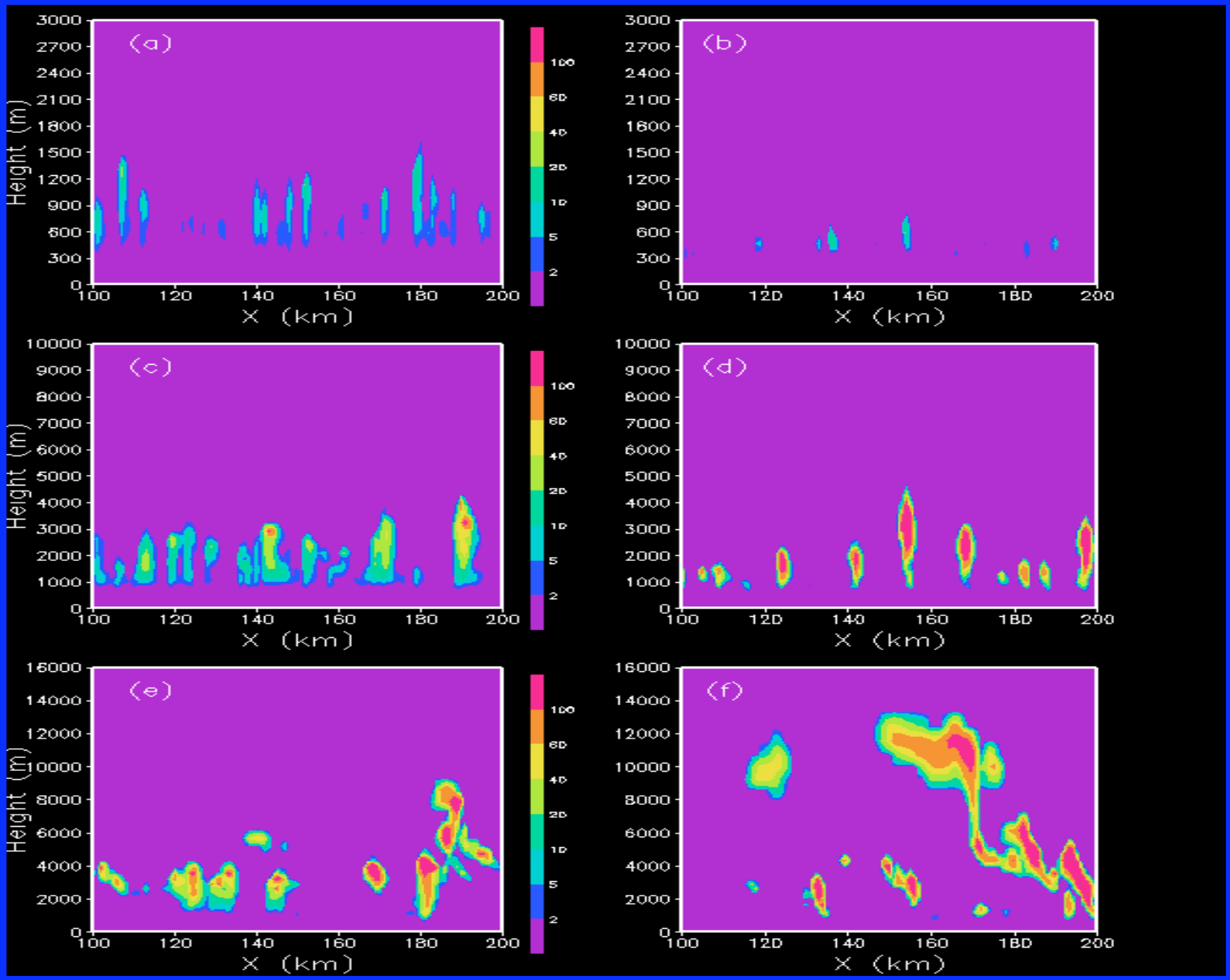
Joint PDF of total water and liquid water potential temperature



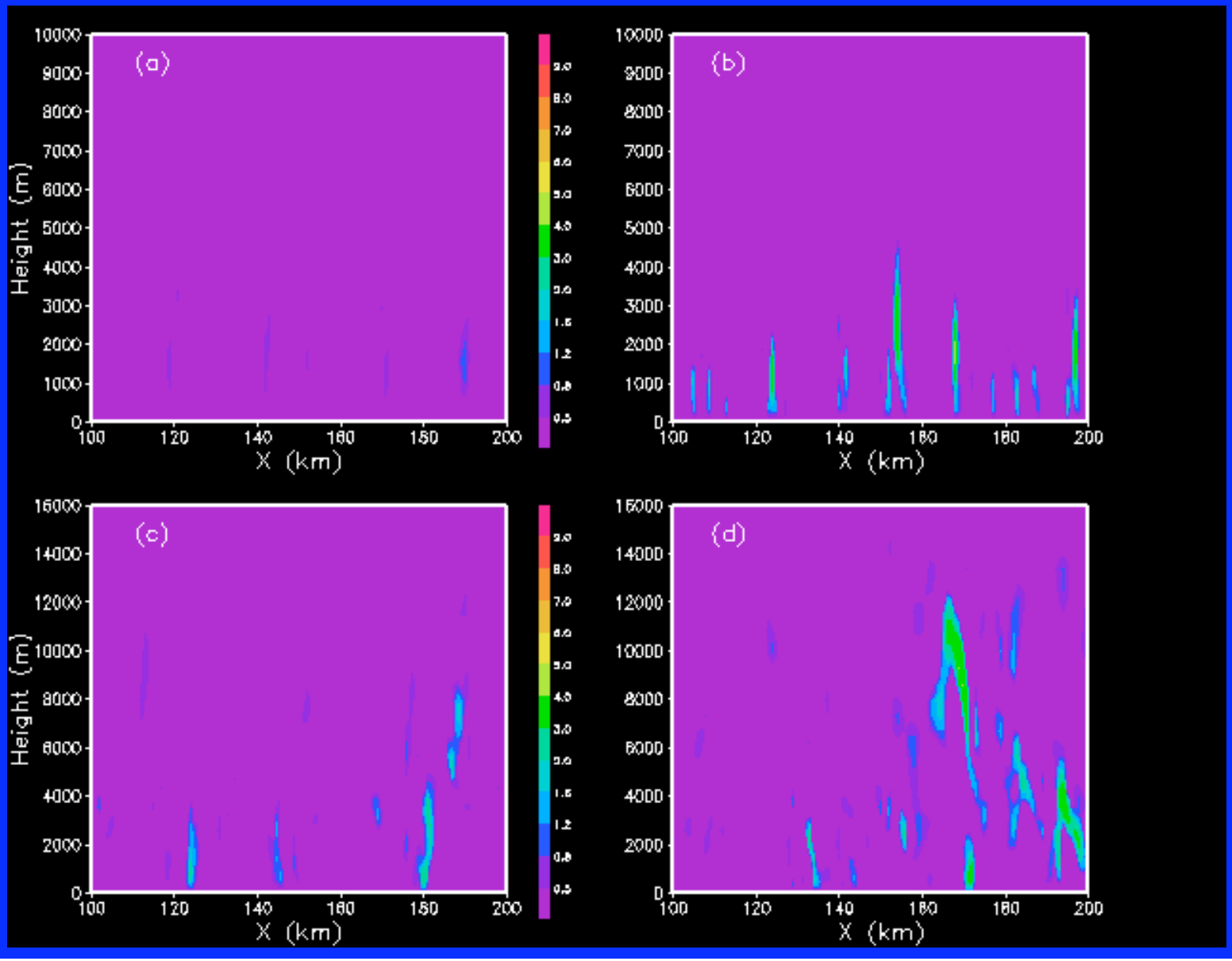
Time-height cross section of cloud fraction



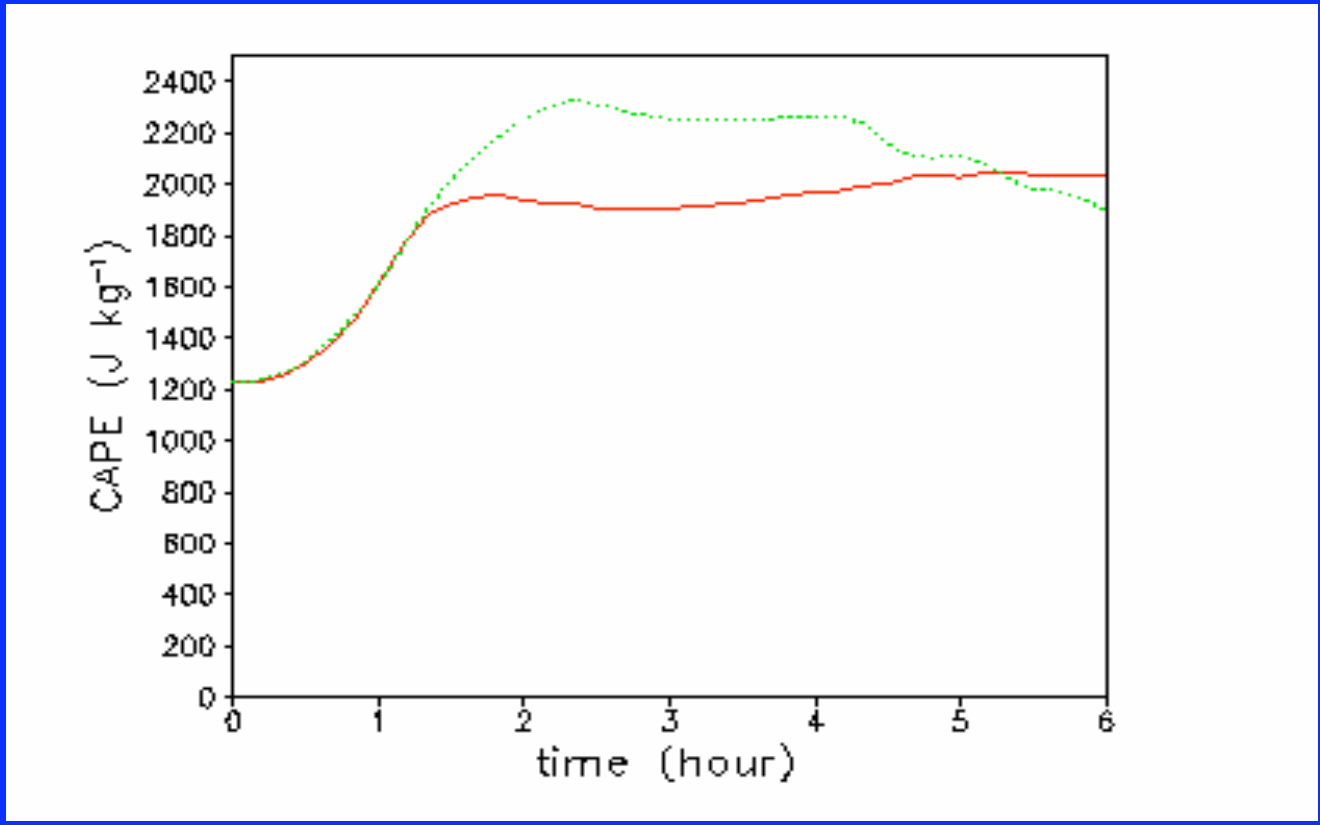
Snapshots of cloud water



Snapshots of vertical velocity



Time series of CAPE



MMF interface (I)

- NASA's fvGCM:

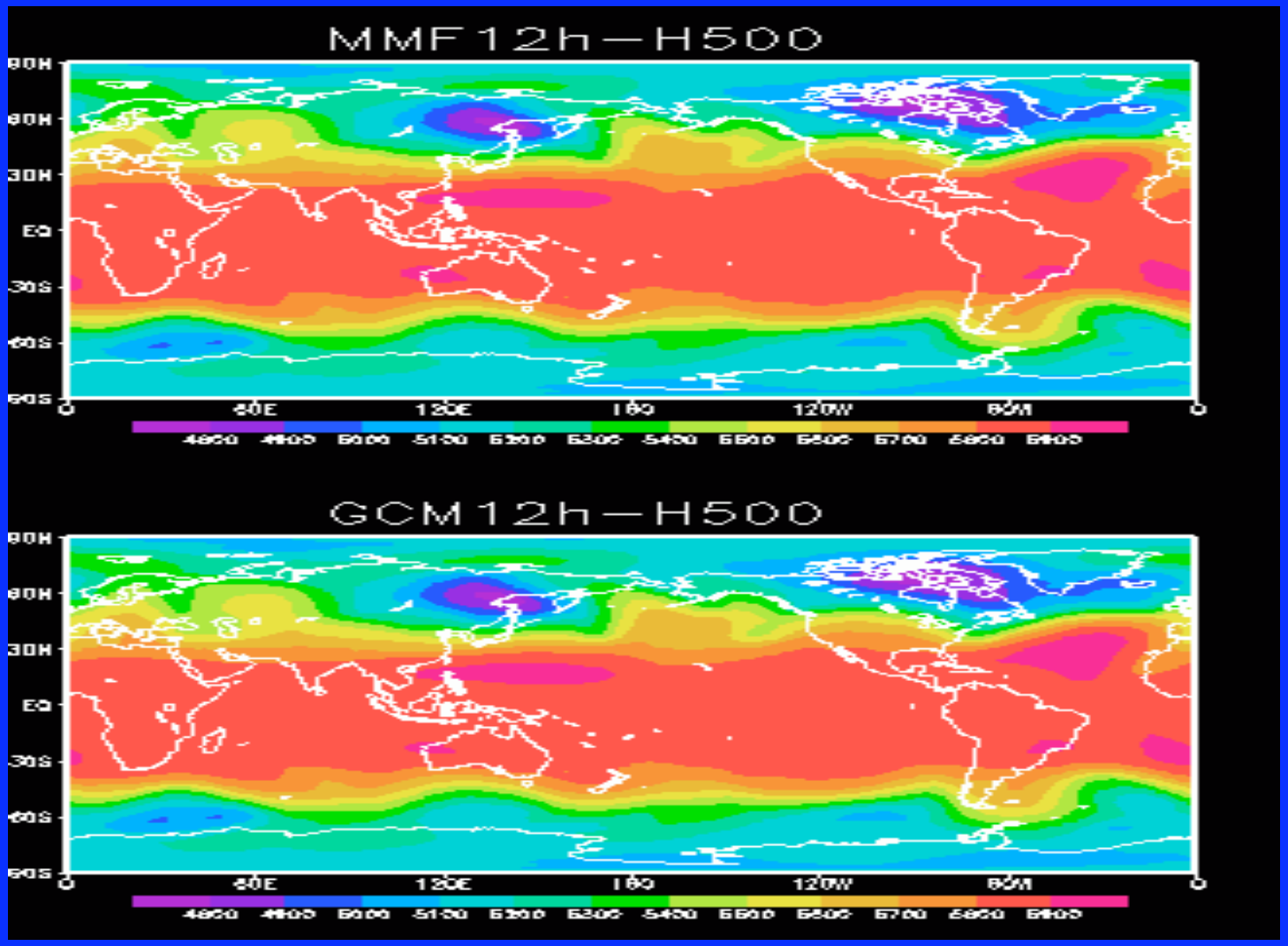
1. 32 levels, p coordinate stretching from surface to about 1mb
2. 2.5x2 degree horizontal resolution
3. Initial condition: 0 UTC 01/01/1998
4. Energy-conserving monotonic piecewise-parabolic interpolation from p coordinate to z coordinate

MMF interface (II)

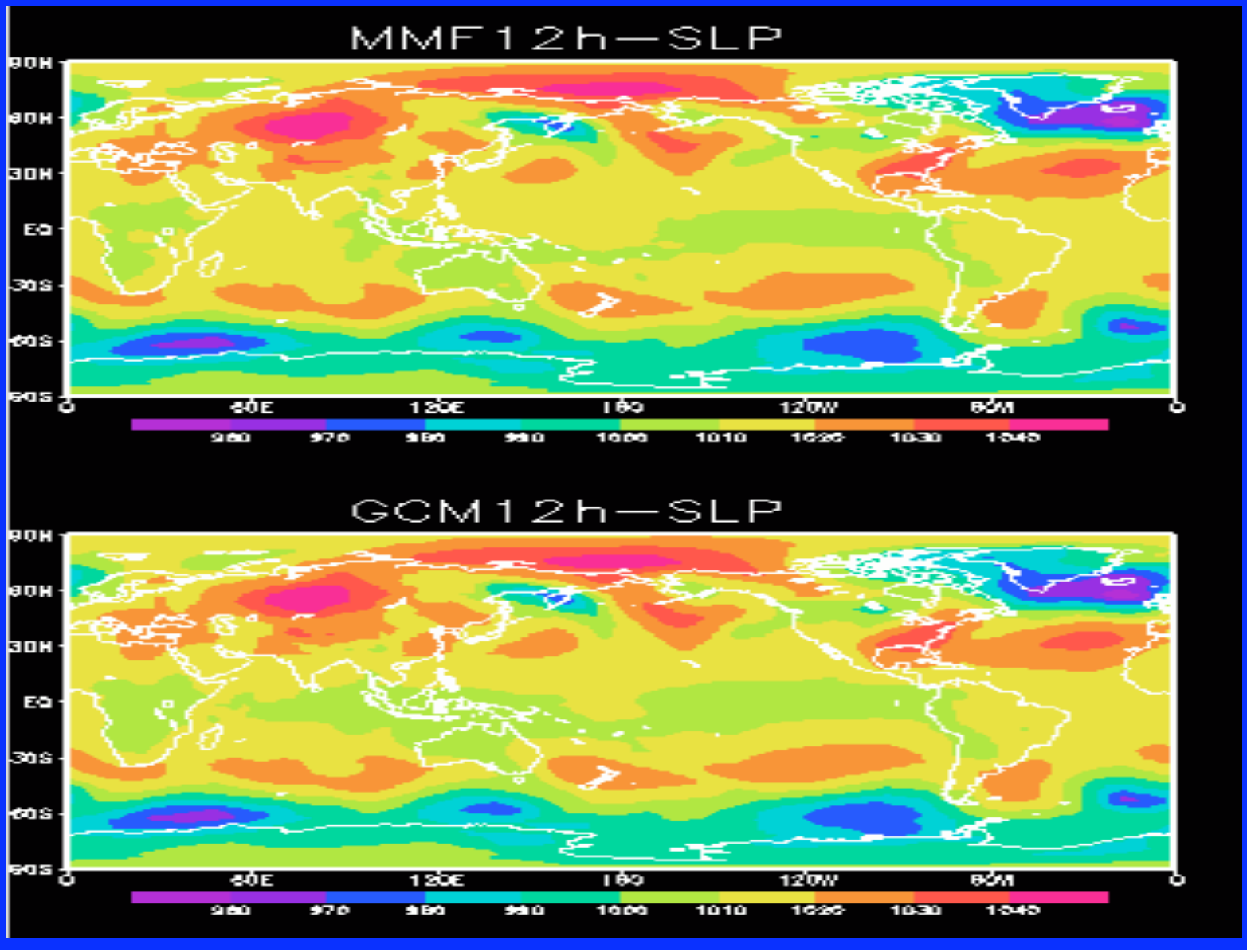
- 2D LaRC CRM:

1. 10 levels, vertical grid-size stretching from 100 m at surface to 4 km at 20 km
2. 8 km horizontal resolution
3. Domain size 256 km
4. Periodic boundary condition
5. No momentum feedback

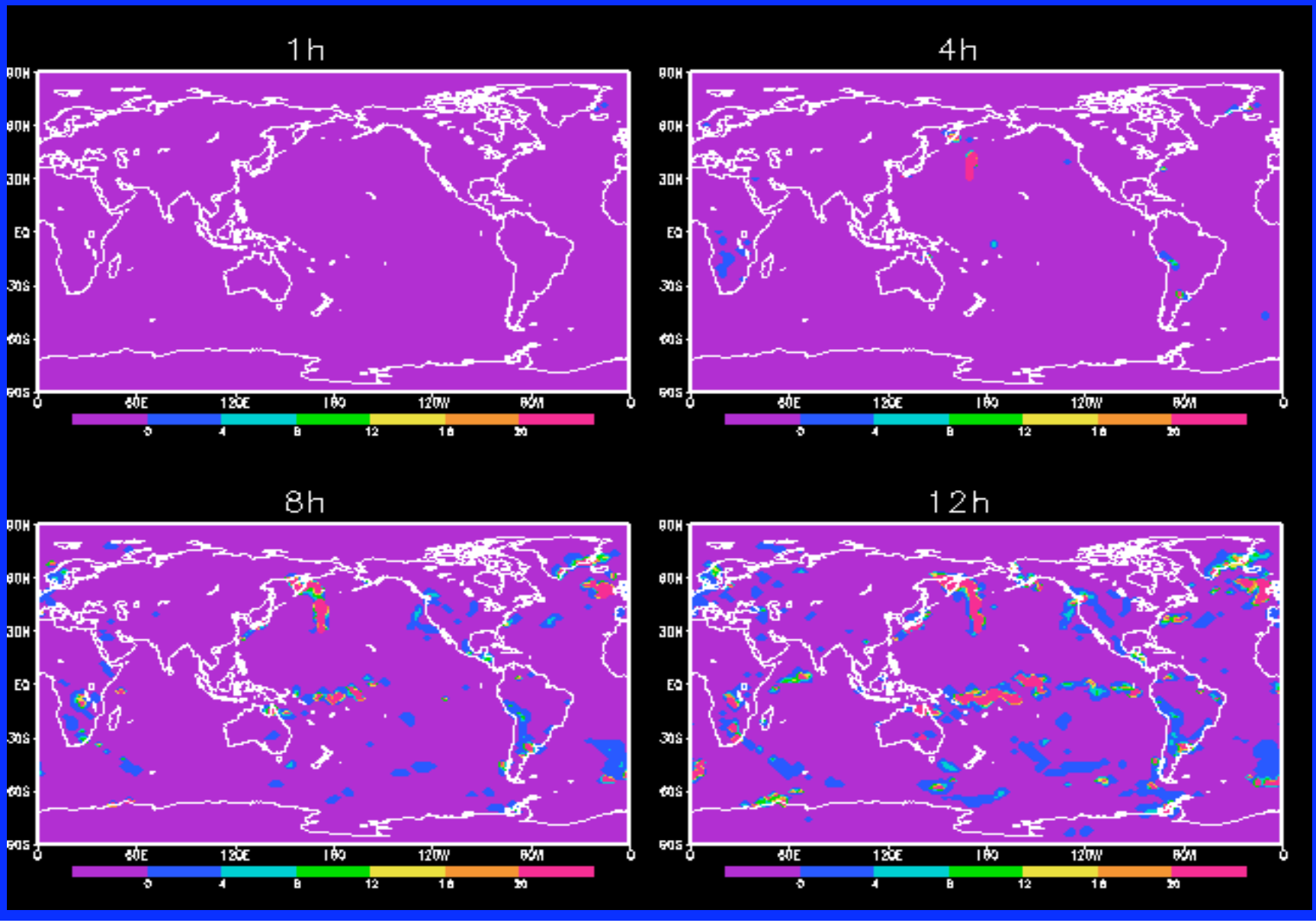
500 hpa Geopotential Height

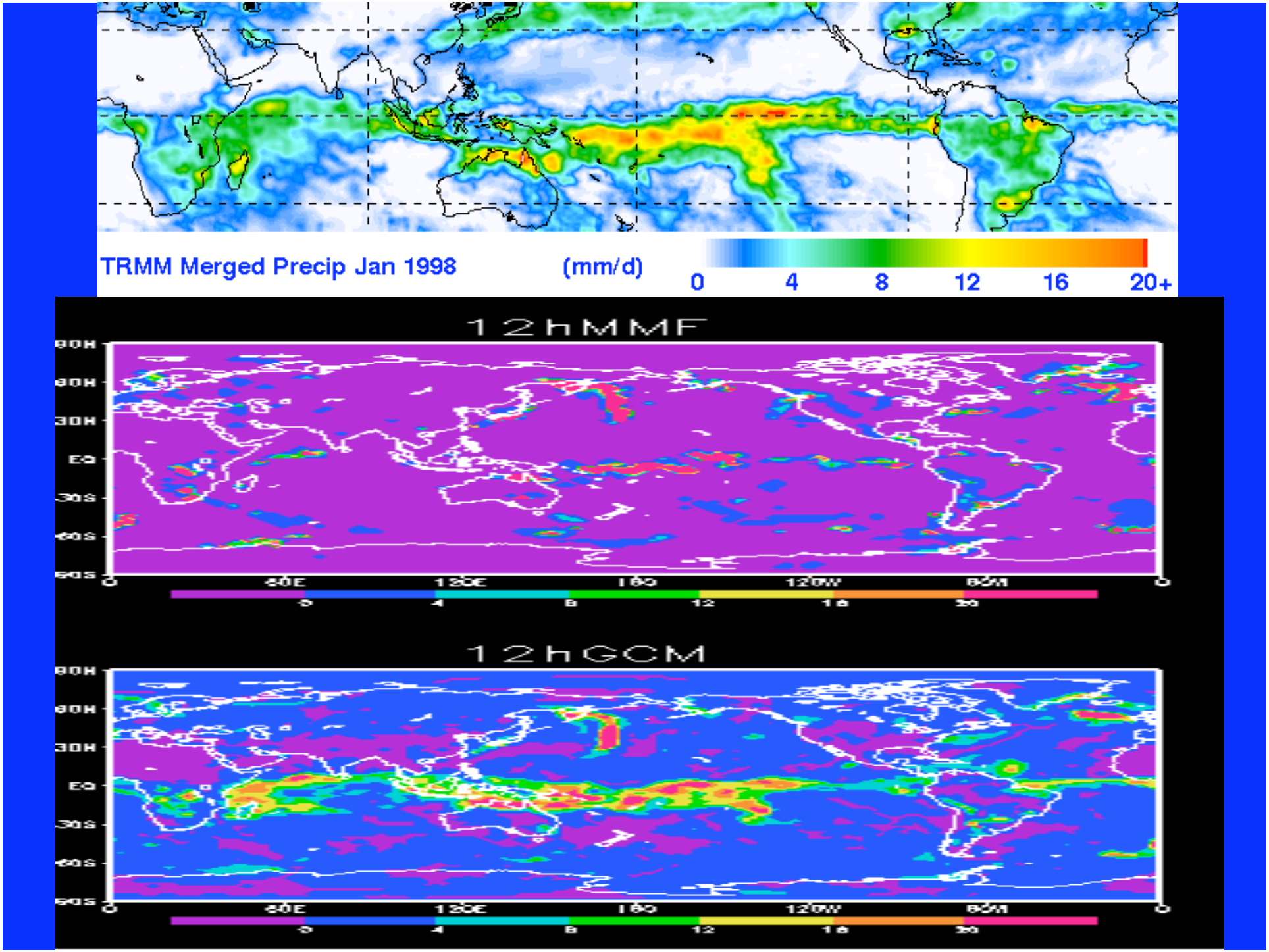


Sea Surface Pressure

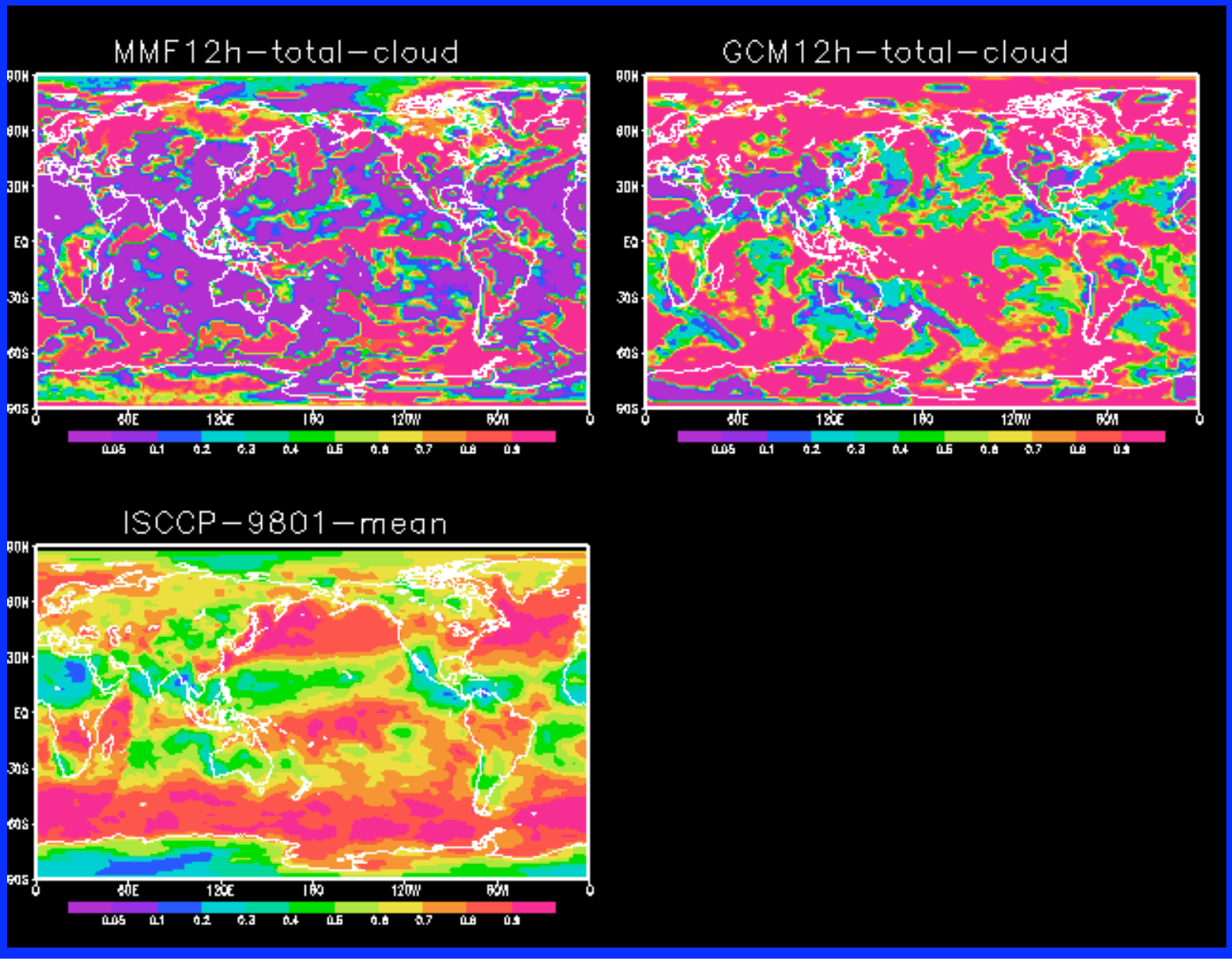


MMF Precipitation

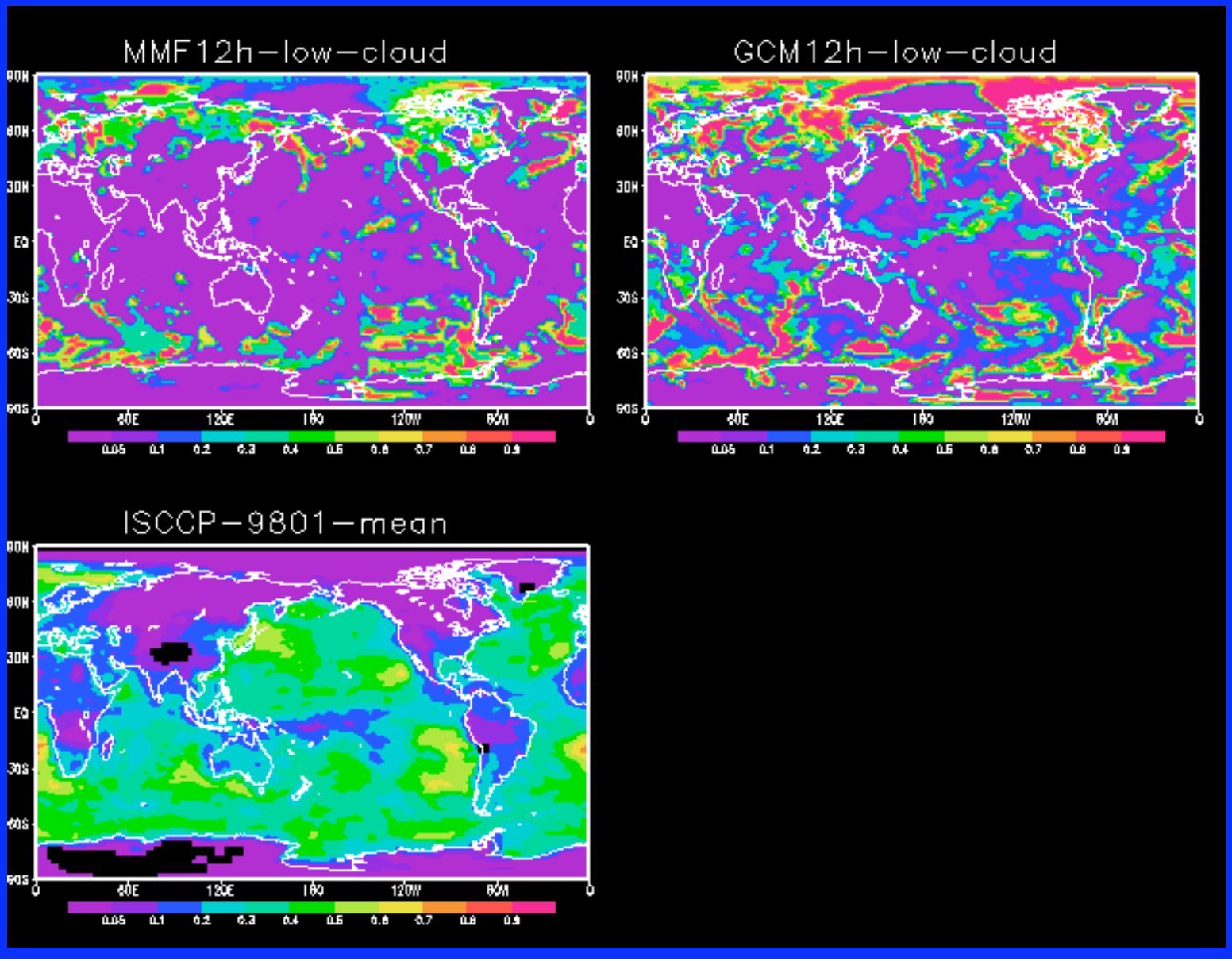



TRMM Merged Precip Jan 1998
(mm/d)
0
4
8
12
16
20+
12hMMF
12hGCM
80N
60N
30N
EQ
30S
60S
90S
0
40E
120E
160
120W
80W
4
8
12
16
20

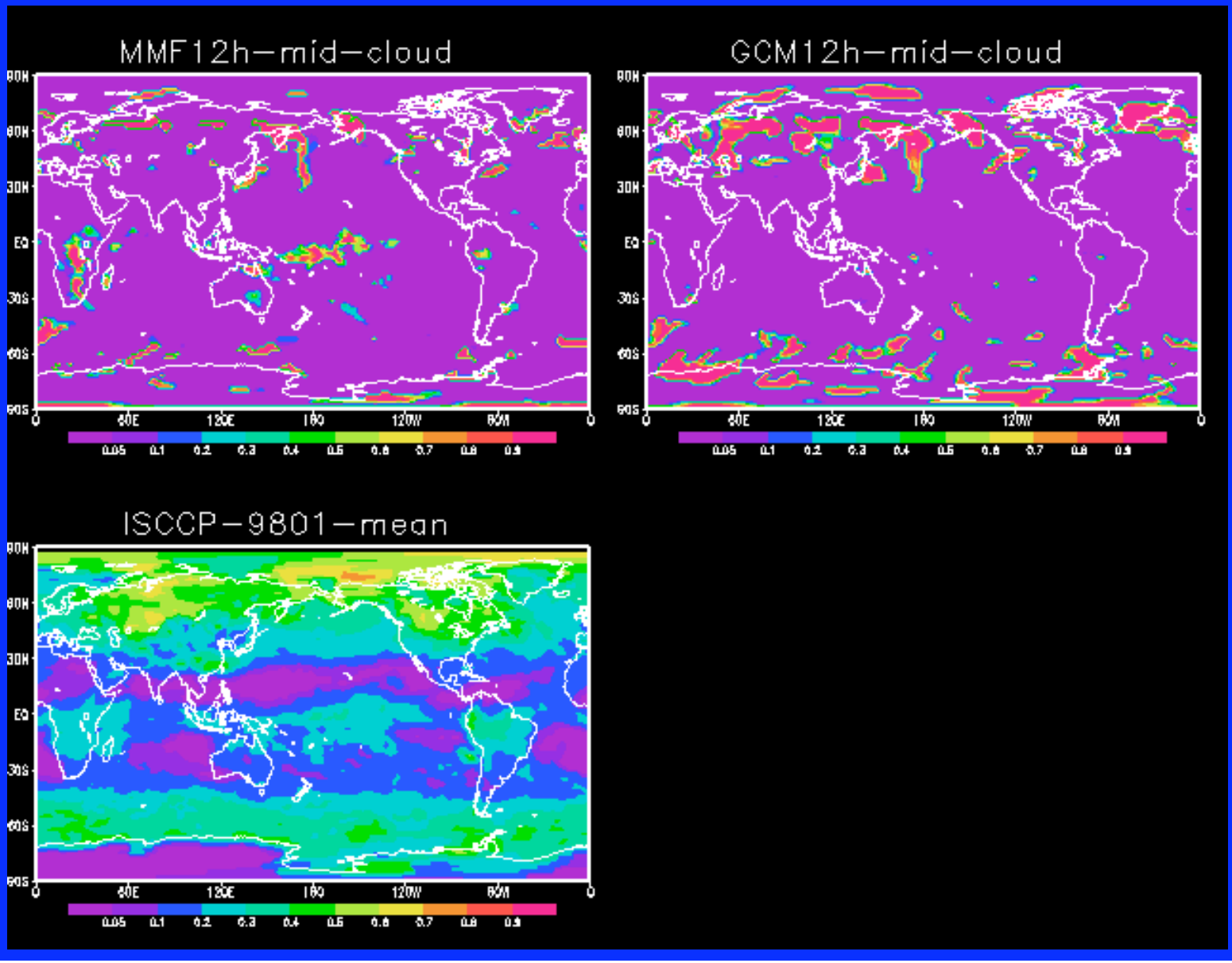
Total cloud


MMF12h−total−cloud
GCM12h−total−cloud
ISCCP−9801−mean
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0.05
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

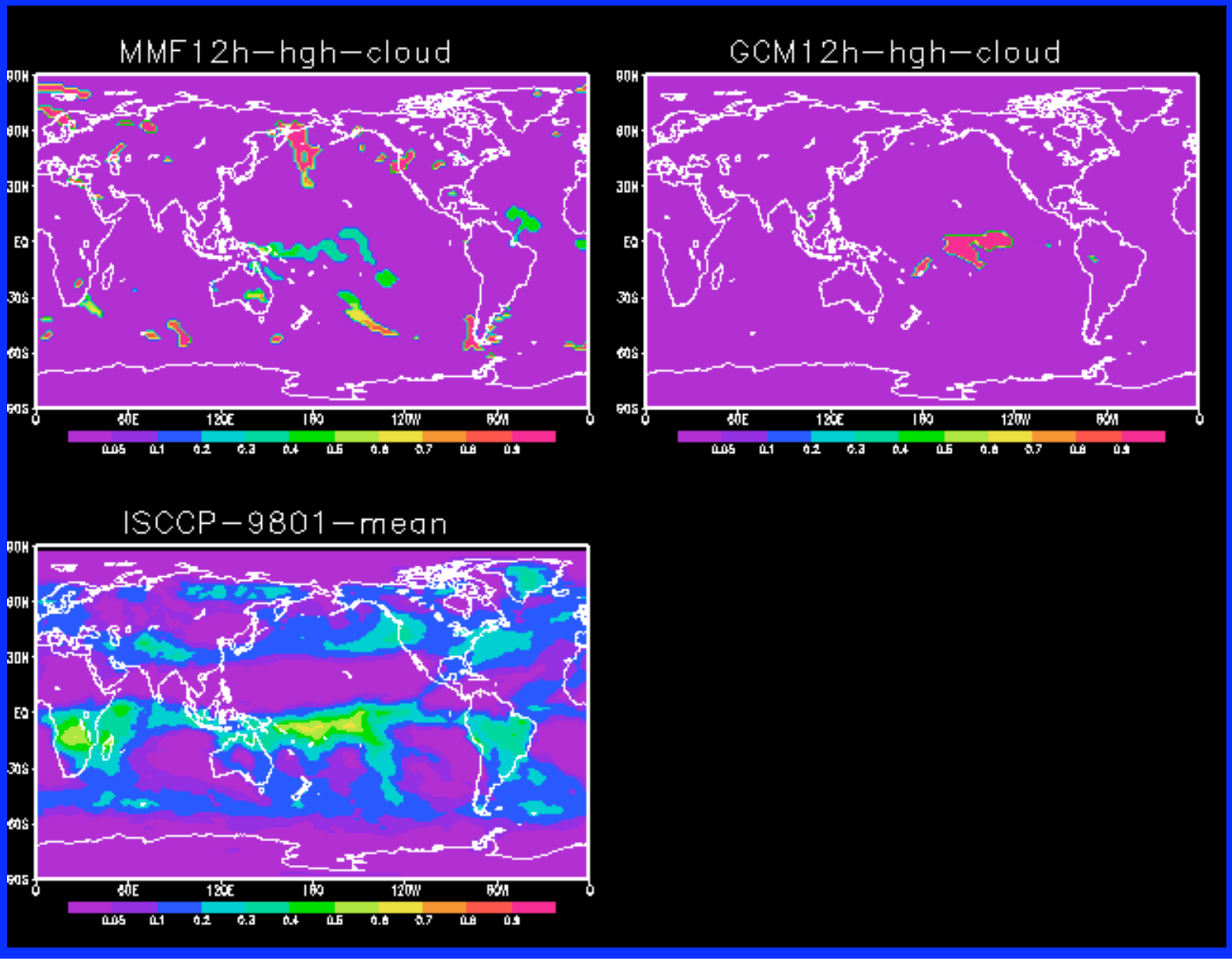
Low Clouds


MMF12h−low−cloud
GCM12h−low−cloud
ISCCP−9801−mean
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0.05
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

Middle level clouds



High clouds


MMF12h−hgh−cloud
GCM12h−hgh−cloud
ISCCP−9801−mean
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0.05
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

Discussion and conclusions

PP CRM

- Computationally less expensive than FP
- More useful information than MP
- Strong ability to simulate a wide range of cloud fields including stratocumulus, shallow cumulus and deep cumulus clouds

Discussion and conclusions

MMF (preliminary but encouraging)

- Produces ITCZ and storm track in 12 h
- Produces good cloud structure in tropical and polar regions
- Produces some low clouds in the subsidence zone
- Reasonable simulation of middle and high clouds in tropical region