Evaluation of Synoptic Cloudiness in the CCSM and Ideas for Improved Parameterization

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Method Description

- Obtain synoptic data from a reanalysis
- Match cloud data with synoptic data
- Average cloud data associated with a similar synoptic situation (compositing)
- Compare composite constructed from observations with composite constructed from GCM output
- Errors in the cloud parameterization will be revealed

This study will compare cloud properties as a function of vertical velocity.

Details of This Study

Domain: North Pacific July 30-60°N, 160-220°E

Observational Data:

- NCEP, ECMWF reanalysis 2.5° x 2.5° 500 mb pressure vertical velocity (ω)
- ERBE 2.5° x 2.5° daily mean shortwave (SW) and longwave (LW) cloud radiative forcing (CRF)
- NASA Water Vapor Project (NVAP) 3° x 3° daily mean all-sky liquid water path (LWP)
- ISCCP 2.5° x 2.5° 3-hourly “cloud type” frequencies

Details of This Study

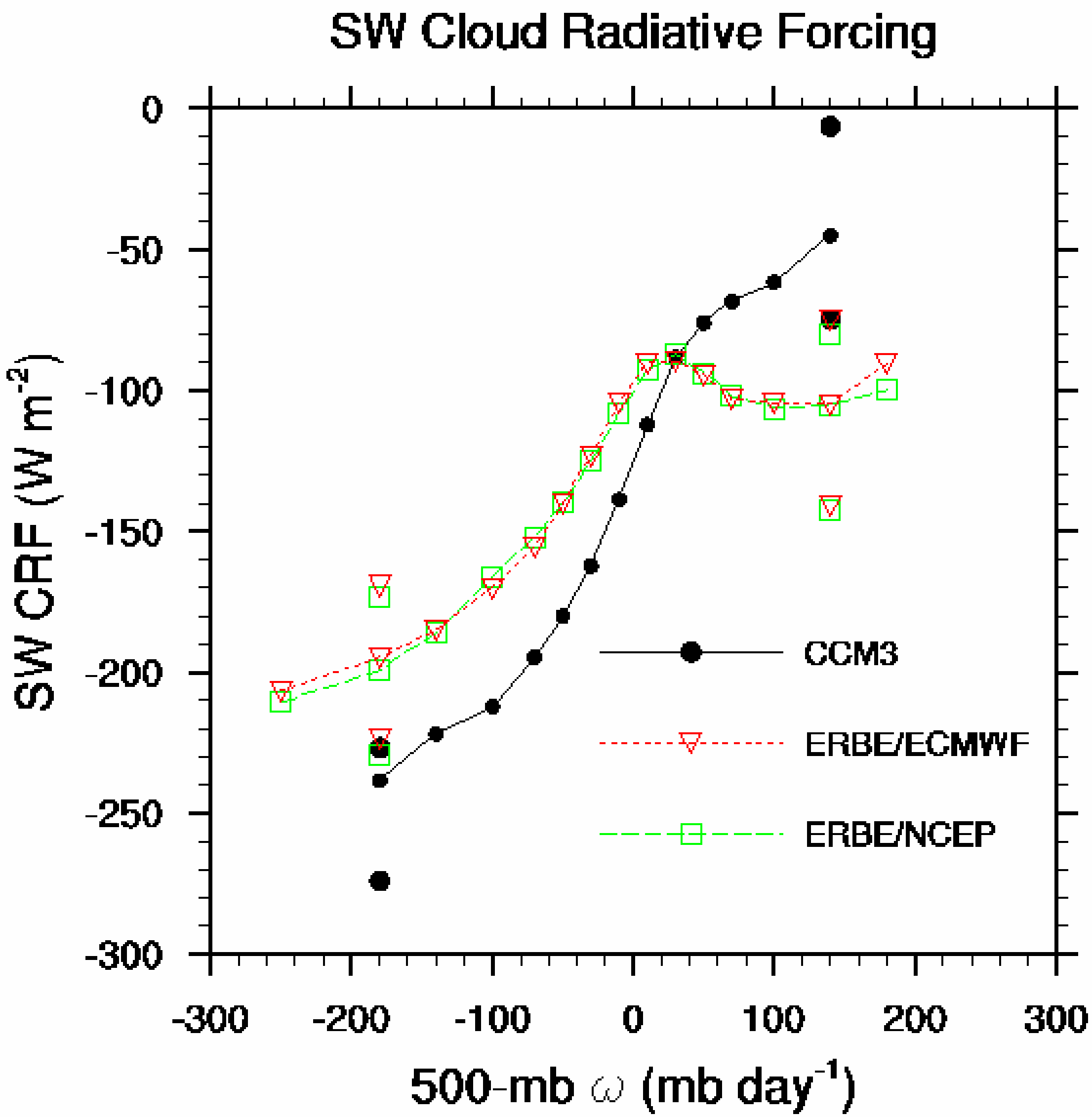
GCM Details:

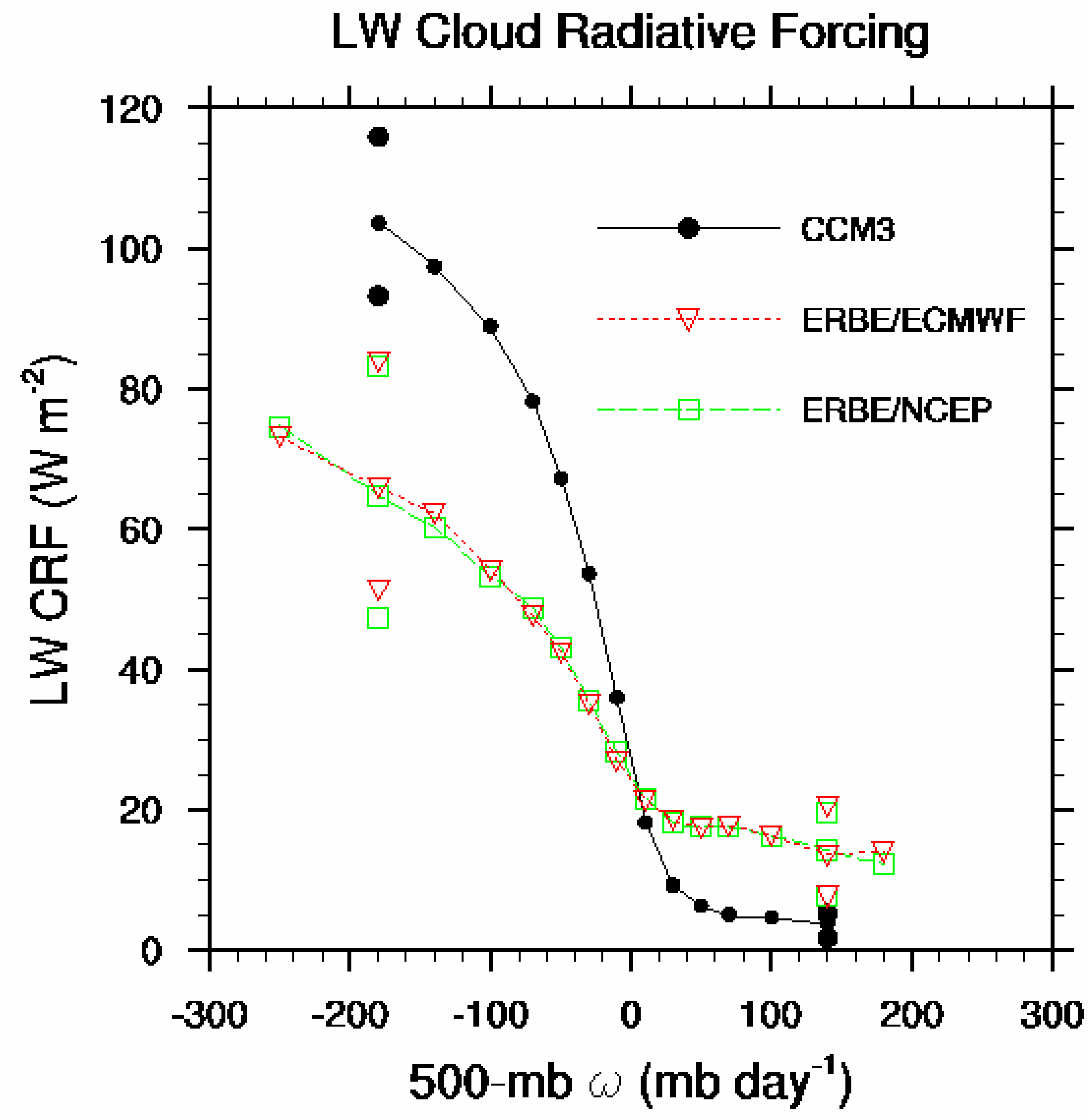
- Community Climate Model Version 3 (CCM3)
- T42 resolution (~2.8° x 2.8°), 18 levels (~1 km)
- Rasch and Kristjánsson prognostic microphysics
- Prescribed monthly observed sea surface temperature for 1985-92

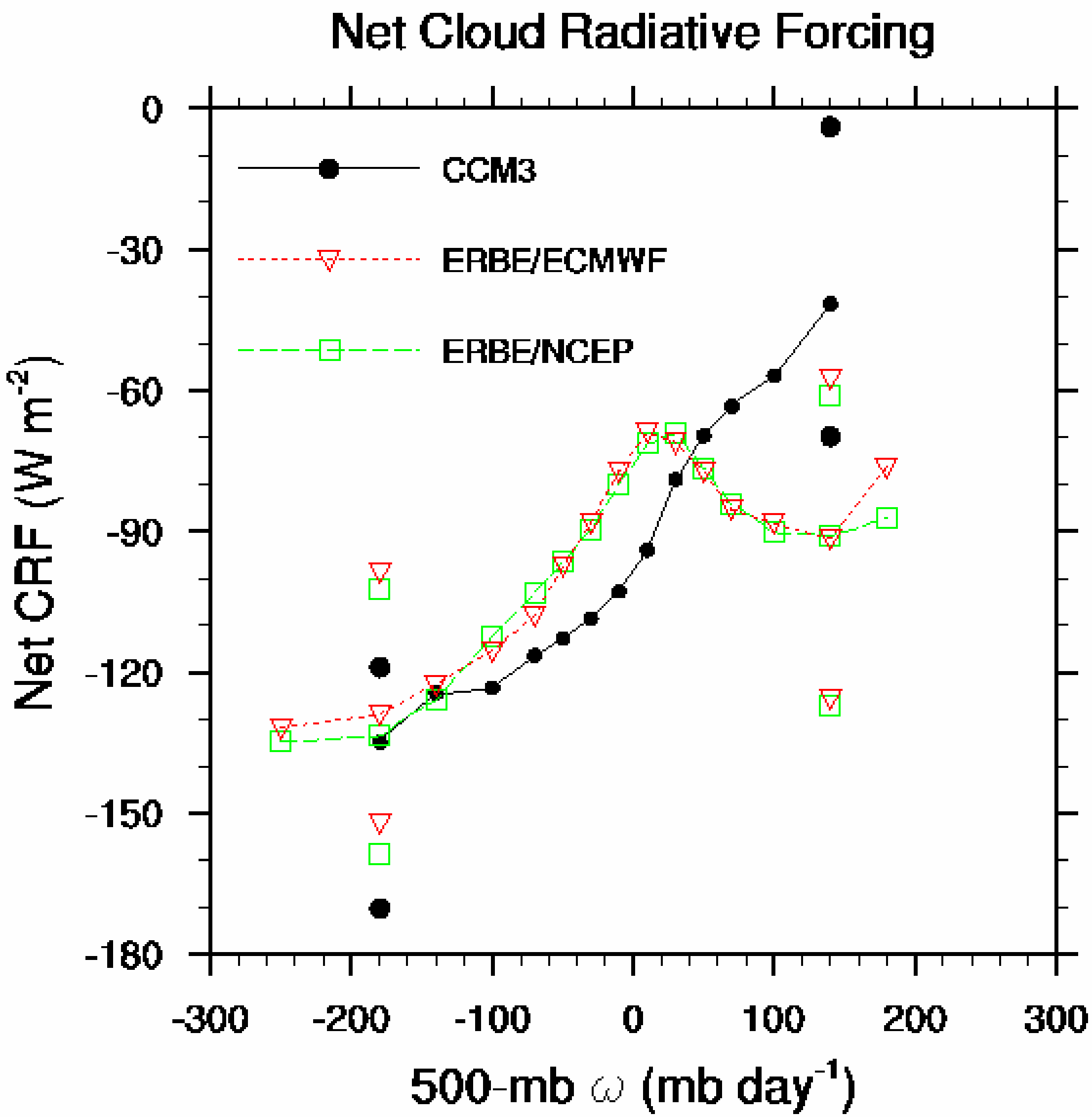
The following figures present observed and simulated SW, LW, and net CRF as functions of vertical velocity.

Over the summertime midlatitude North Pacific:

- CCM overproduces SW and LW CRF under ascent conditions
- CCM underproduces SW and LW CRF under subsidence conditions


SW Cloud Radiative Forcing
0
-50
-100
-150
-200
-250
-300
SW CRF (W m-2)
-300
-200
-100
0
100
200
300
500-mb ω (mb day-1)
CCM3
ERBE/ECMWF
ERBE/NCEP


LW Cloud Radiative Forcing
LW CRF (W m-2)
500-mb ω (mb day-1)
CCM3
ERBE/ECMWF
ERBE/NCEP
0
20
40
60
80
100
120
-300
-200
-100
0
100
200
300

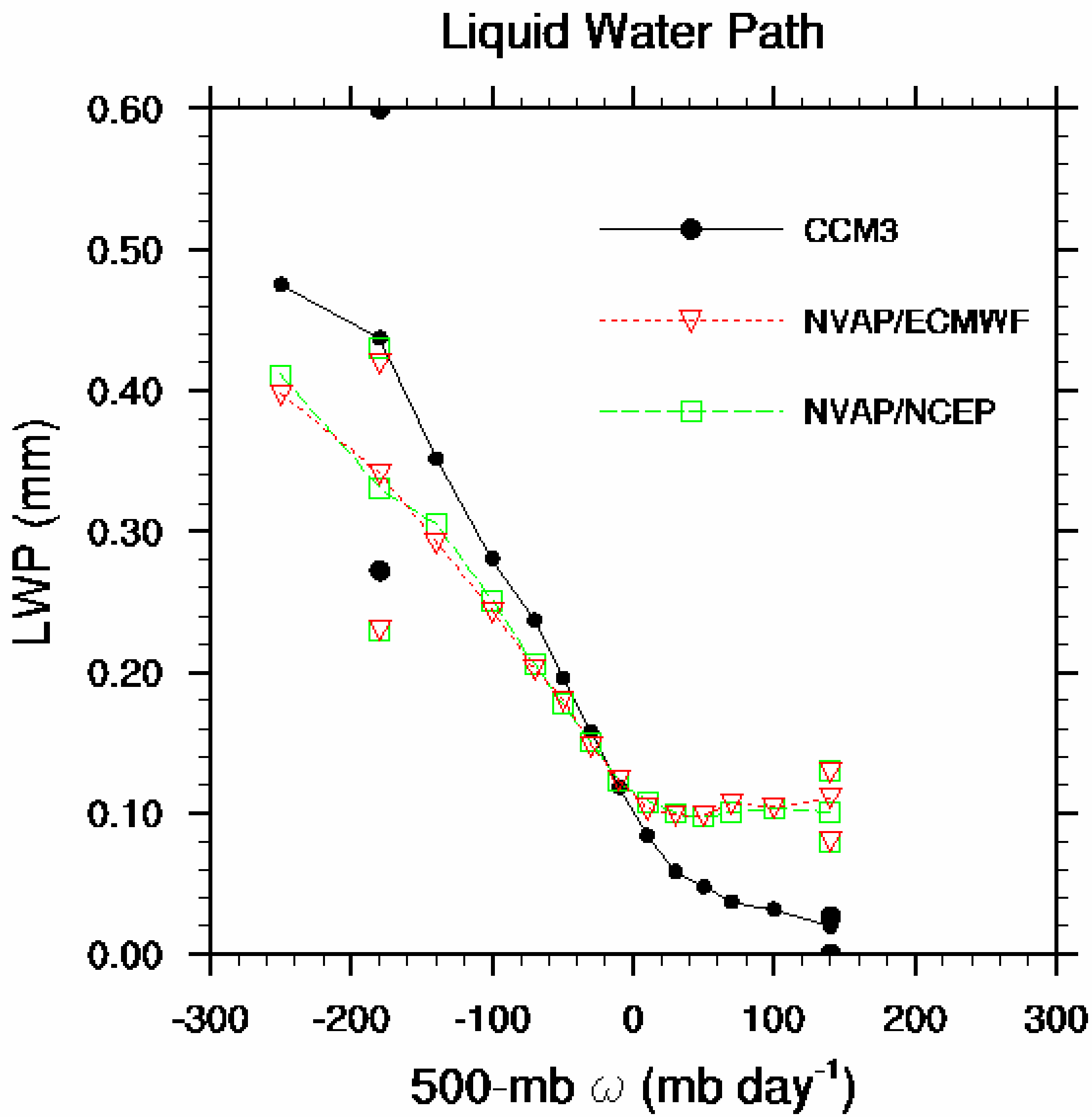


Net Cloud Radiative Forcing
CCM3
ERBE/ECMWF
ERBE/NCEP
0
-30
-60
-90
-120
-150
-180
Net CRF (W m-2)
-300
-200
-100
0
100
200
300
500-mb ω (mb day-1)

The following figure presents observed and simulated all-sky LWP (cloud-only LWP x cloud fraction) as a function of vertical velocity.

Over the summertime midlatitude North Pacific:

- CCM underproduces all-sky LWP under subsidence conditions

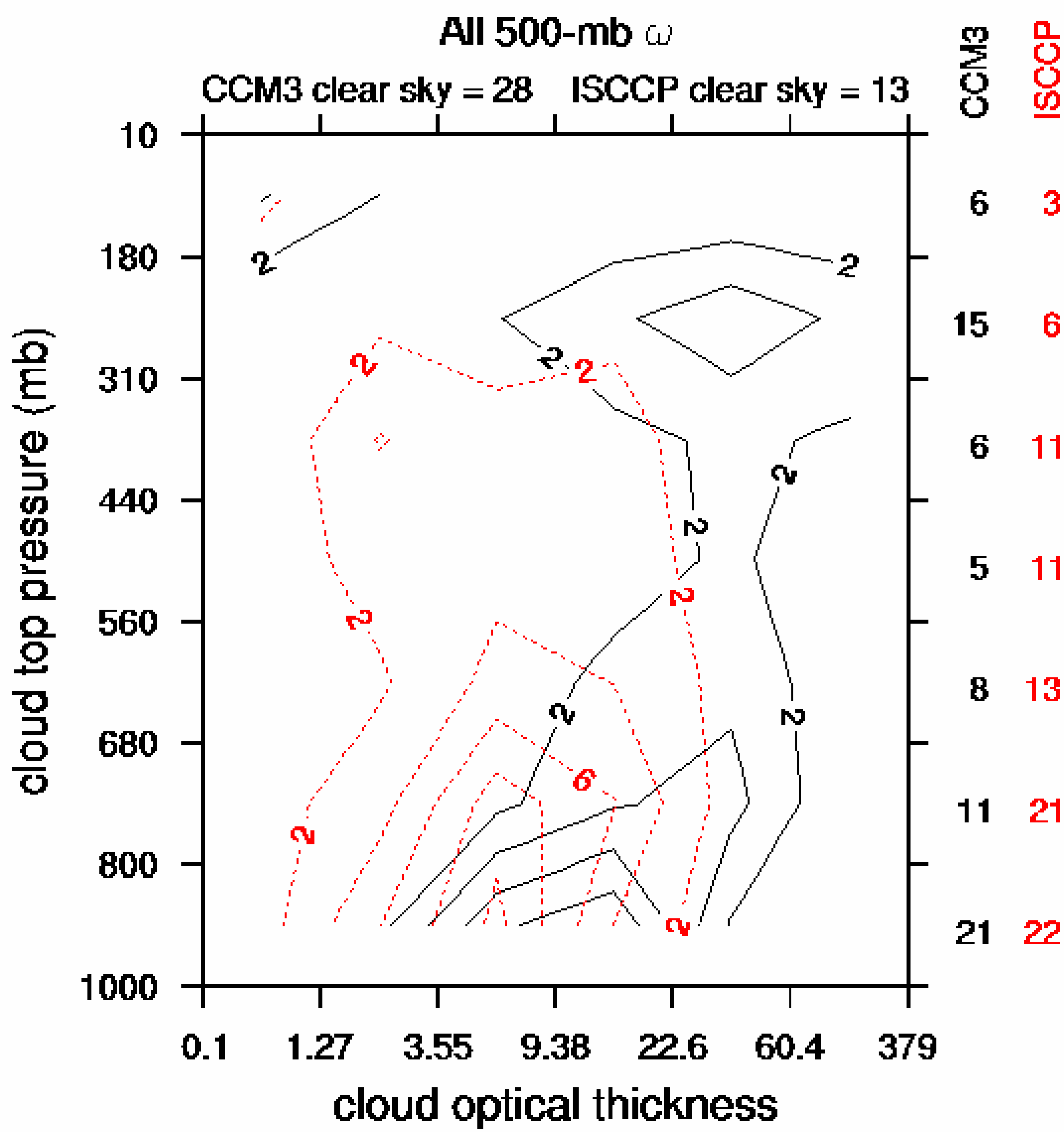


Liquid Water Path
CCM3
NVAP/ECMWF
NVAP/NCEP
LWP (mm)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
-300
-200
-100
0
100
200
300
500-mb ω (mb day-1)

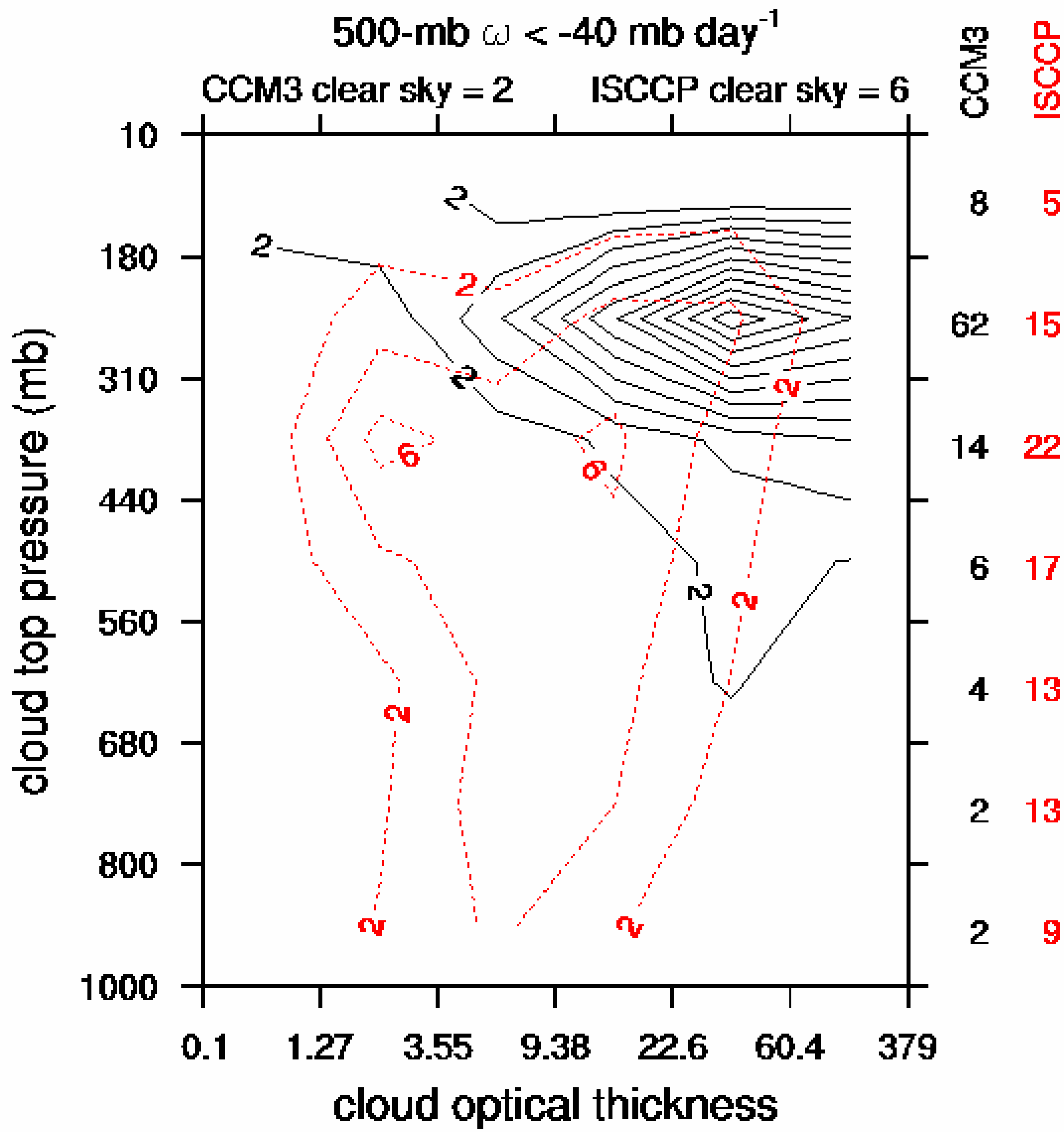
The following figures present the observed and simulated frequency distribution of cloudiness as a function of cloud top pressure and optical thickness for vertical velocity categories (contour interval is 2%). Cloud cover (satellite view) at each level is listed on the right.

Over the summertime midlatitude North Pacific:

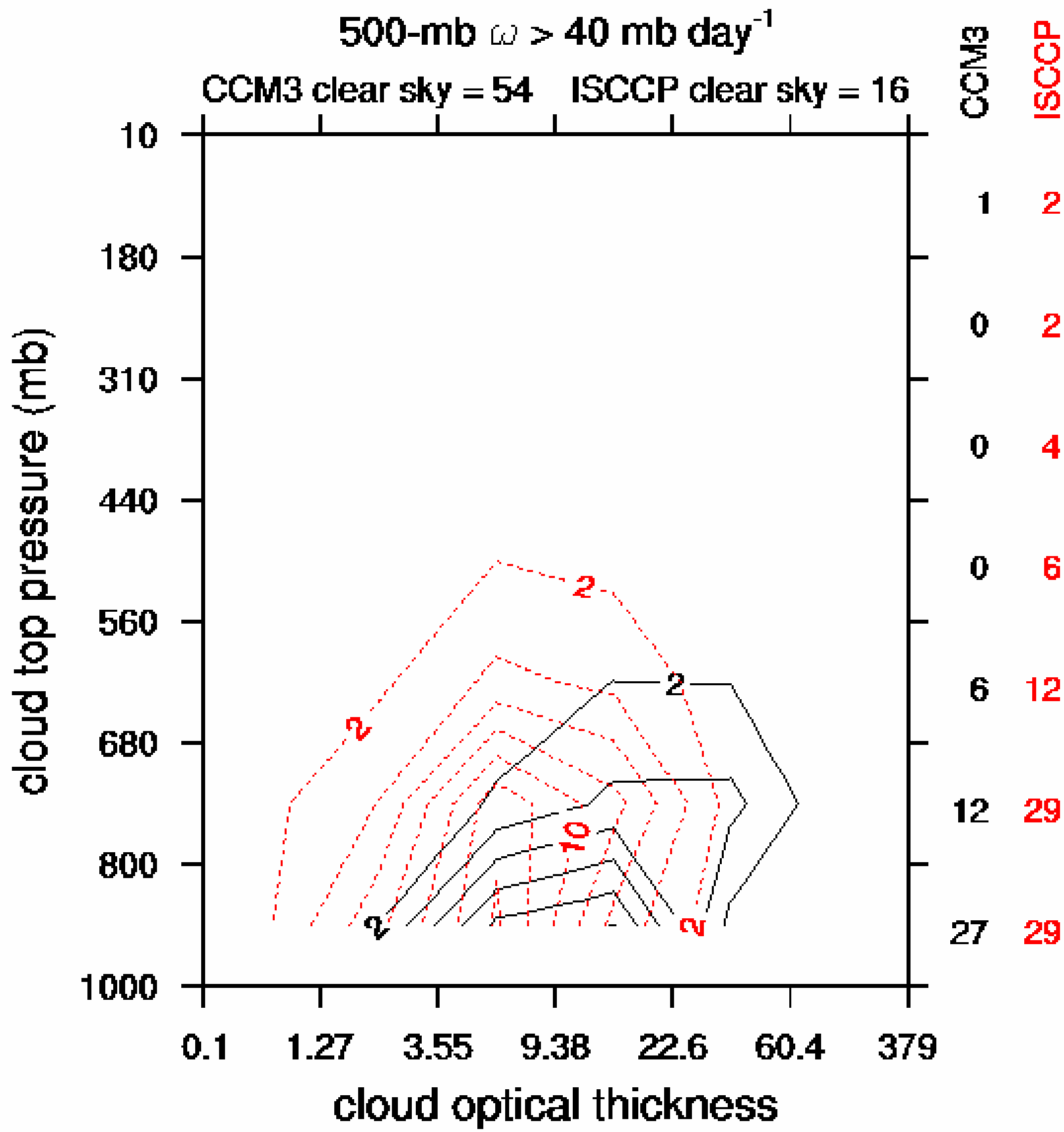
- CCM overproduces high-cloud optical thickness and cover under ascent conditions
- CCM overproduces low-cloud optical thickness under subsidence conditions
- CCM underproduces low-cloud cover and height under subsidence conditions



All 500-mb ω
CCM3 clear sky = 28 ISCCP clear sky = 13
CCM3
ISCCP
cloud top pressure (mb)
10
180
310
440
560
680
800
1000
cloud optical thickness
0.1
1.27
3.55
9.38
22.6
60.4
379
6 3
15 6
6 11
5 11
8 13
11 21
21 22



500-mb ω < -40 mb day-1
CCM3 clear sky = 2
ISCCP clear sky = 6
CCM3
ISCCP
cloud top pressure (mb)
10
180
310
440
560
680
800
1000
cloud optical thickness
0.1
1.27
3.55
9.38
22.6
60.4
379
8 5
62 15
14 22
6 17
4 13
2 13
2 9



500-mb ω > 40 mb day-1
CCM3 clear sky = 54
ISCCP clear sky = 16
CCM3
ISCCP
cloud top pressure (mb)
10
180
310
440
560
680
800
1000
0.1
1.27
3.55
9.38
22.6
60.4
379
cloud optical thickness
1 2
0 2
0 4
0 6
6 12
12 29
27 29

Attribution of Errors

- High-cloud cover and optical thickness are overproduced because the entire tropospheric grid column becomes saturated under resolved ascent
- Low-cloud cover is underproduced because boundary-layer processes are not correctly parameterized

These errors directly impact large-scale co-variability between cloudiness and other climate parameters on interannual and decadal timescales.

Ideas for Improved Parameterization

- The lack of subgrid frontal cloud variability in CCM results from cloud generation by resolved ascent alone
- The impact of mesoscale frontal circulations on the cloud distribution should be implemented
- The presence of conditional symmetric instability (CSI) has been associated with frontal rain bands (Bennetts and Hoskins 1979; Emanuel 1985)
- This motivates investigation into a frontal cloud parameterization based on CSI.