Variability of extratropical cloudiness and related meteorological parameters in the CCSM2

Joel Norris
Scripps Institution of Oceanography
For brevity I will focus on low-level clouds over the ocean during the JJA season

- Low-level oceanic clouds are the most common type in the extratropics
- Cloud radiative forcing is very large over northern midlatitude oceans during JJA
- Subtropical stratocumulus coverage is large in both hemispheres during JJA
Climatological Low Cloud Cover During JJA

CCSM2 (0191-0410)  Observed (1952-1996)

colors: cloud cover (every 10%)

model output: CLDLOW

observations: surface synoptic cloud reports
Correlation between Low Cloud and SST JJA Anomalies

CCSM2 (0191-0410)  Observed (1952-1996)

colors: local correlation (every 20%)
contours: climatological cloud cover (every 10%)

model output: CLDLOW and TS
observations: surface synoptic cloud and SST reports
Regression of Cloud Radiative Forcing on SST JJA Anomalies

CCSM2 SWCRF (0191-0410)  CCSM2 LWCRF (0191-0410)

colors: local regression coefficient (every 5 W m^{-2} K^{-1})
SW contours: climatological CRF (every 20 W m^{-2})
LW contours: climatological CRF (every 10 W m^{-2})

model output: SWCF, LWCF, and TS
First Summary

- CCSM2 does reproduce the major features of observed climatological JJA extratropical oceanic low cloudiness
- CCSM2 does not reproduce the specific magnitude and location of subtropical stratocumulus
- CCSM2 does reproduce negative correlations between interannual JJA low cloud and SST anomalies observed in the extratropics
- Positive net CRF anomalies are associated with positive SST anomalies in CCSM2, implying a positive cloud feedback on SST in the extratropics
Independently Calculated Low Cloud and SST JJA EOF 1

**CCSM2** (0191-0410)
- Cloud–SST correlation = 63%
- Cloud EOF1 variance = 22%
- SST EOF1 variance = 35%

**Observed** (1952-1996)
- Cloud–SST correlation = 75%
- Cloud EOF1 variance = 28%
- SST EOF1 variance = 30%

colors: cloud cover (every 1%)
contours: SST (every 0.1°C)
Independently Calculated Low Cloud and SLP JJA EOF 1

CCSM2 (0191-0410)
Observed (1952-1996)

colors: cloud cover (every 1%)
contours: SLP (every 0.2 mb)

CCSM2
Cloud–SLP correlation = 50%
Cloud EOF1 variance = 22%
SLP EOF1 variance = 64%

Observed
Cloud–SLP correlation = 11%
Cloud EOF1 variance = 28%
SLP EOF1 variance = 40%
Nimbostratus and Large Scale Precipitation JJA EOF 1

CCSM2 (0191-0410)

Observed (1952-1996)

colors: precip rate (0.1 mm/dy)  
contours: SLP (every 0.2 mb)

CCSM2
Precip–SLP correlation = 51%  
Precip EOF1 variance = 27%

model output: PRECL

Observed
Ns–SST correlation = 41%  
Ns EOF1 variance = 13%

observations: present weather report
Correlations of JJA EOF 1 Time Series

<table>
<thead>
<tr>
<th></th>
<th>CCSM2 (0191-0410)</th>
<th>Observed (1952-1996)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Cloud</td>
<td>SST</td>
</tr>
<tr>
<td>Precip</td>
<td>39</td>
<td>12</td>
</tr>
<tr>
<td>SLP</td>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>SST</td>
<td>63</td>
<td></td>
</tr>
</tbody>
</table>
Second Summary

- Leading patterns of low cloud and SST interannual variability are coupled in both CCSM2 and observations.
- Leading patterns of low cloud and SLP interannual variability are coupled in CCSM2 but not observations.
- Anomalous southwesterly flow is associated with increased low cloud cover in CCSM2.
- Leading patterns of precipitation and SLP interannual variability are coupled in CCSM2 but not observations.
- Leading patterns of precipitation and SST interannual variability are coupled in observations but not CCSM2.
Daily Cloud Radiative Forcing as a Function of Vertical Velocity

Composited during July over 30-60°N, 160-220°E
Daily Cloud Radiative Forcing as a Function of Vertical Velocity

Composited during July over 30-60°N, 160-220°E
Daily All-Sky Liquid Water Path as a Function of Vertical Velocity

Composited during July over 30-60°N, 160-220°E
Third Summary

- CCSM2 overproduces both SWCRF and LWCRF under conditions of synoptic ascent.
- CCSM2 underproduces both SWCRF and LWCRF under conditions of synoptic descent.
- The SW bias exceeds the opposing LW bias.
- SWCRF under all conditions is larger in CAM2 than in CCM3 (with prognostic water) due to greater LWP.
CCSM2 Synoptic Cloud Processes over Extratropical Oceans during Summer

Underproduction of cold sector stratocumulus

Missing low cloud breakup

Enhanced low cloud formation

Overproduction of frontal cloudiness

Result: CCSM2 low cloudiness has realistic coupling to variability in the SST gradient and storm track but is unrealistically sensitive to changes in low-level circulation.