Upper ocean heat budget in the southeast Pacific stratus cloud region using eddy-resolving HYCOM

Yangxing Zheng (University of Colorado)
Toshi Shinoda (Naval Research Laboratory)
George Kiladis (NOAA-ESRL/PSD)
Jialin Lin (Ohio State University)
Joseph Metzger (Naval Research Laboratory)
Harley Hurlburt (Naval Research Laboratory)
Benjamin Geise (Texas A&M Univ.)
Upper ocean heat budget in the southeast Pacific stratus cloud region using eddy-resolving HYCOM

Layered Ocean Model Workshop (LOM 2009), Miami, FL
Stratus cloud decks ==> important role in regional and global climate

Most coupled GCMs have problems in producing realistic stratus clouds.

Upper ocean processes that control SST is crucial for simulating stratus clouds

Surface mooring measurements by WHOI since October 2000 (Colbo and Weller 2007)

New campaign: VAMOS Ocean-Cloud-Atmosphere-Land Study (VOCALS)
   Intensive Observations: VOCALS Regional Experiment (Oct. 2008)
Upper ocean heat balance (upper 250m) at the buoy site (Colbo and Weller, 2007)

<table>
<thead>
<tr>
<th>Term</th>
<th>Estimate (W/m²)</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface heat flux</td>
<td>44 (± 5)</td>
<td>IMET buoy</td>
</tr>
<tr>
<td>Horizontal heat advection by Ekman transport</td>
<td>6 (± 4)</td>
<td>QuikSCAT winds Satellite SST</td>
</tr>
<tr>
<td>Horizontal heat advection by geostrophic transport</td>
<td>-20 (± 5)</td>
<td>IMET velocity, temperature Historical temperature</td>
</tr>
<tr>
<td>Ekman pumping</td>
<td>2.5 (± 5)</td>
<td>QuikSCAT winds IMET temperature</td>
</tr>
<tr>
<td>Eddy flux divergence</td>
<td>-30</td>
<td>Residual</td>
</tr>
<tr>
<td>Vertical diffusion</td>
<td>-3 (± 2)</td>
<td>IMET temperature</td>
</tr>
</tbody>
</table>
Hypothesis (Colbo and Weller 2007)

“We postulate that the eddy flux divergence represents the effect of the cold coherent eddies formed near the coast..... the upwelled water does influence the offshore structure, but through the fluctuating mesoscale flow not the mean transport.”

Issues

Upper ocean processes which balance the positive (warming) surface heat flux

Representativeness of the IMET site for the entire stratus cloud region

Role of eddies
Models

**Global HYCOM**
- Horizontal resolution: 1/12 deg. \( \times \) 1/12 deg.
- No data assimilation

**SODA**
- Horizontal resolution: 0.4 deg. \((\text{lon})\) \( \times \) 0.25 deg.\((\text{lat})\)
- Period: 1980-2005
- Data assimilation

Relative importance of horizontal advection and eddy flux divergence for the upper ocean heat balance
Comparison of heat budget at 85W, 20S

<table>
<thead>
<tr>
<th></th>
<th>Colbo and Weller (2007)</th>
<th>HYCOM</th>
<th>SODA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface heat flux</td>
<td>44</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Geostrophic</td>
<td>-20</td>
<td>-45</td>
<td>-21</td>
</tr>
<tr>
<td>Ekman</td>
<td>6</td>
<td>-44</td>
<td>11</td>
</tr>
<tr>
<td>Eddy flux div.</td>
<td>-30</td>
<td>42</td>
<td>-19</td>
</tr>
</tbody>
</table>

Ekman currents => total - geostrophic
Upper 50m
Upper 50m

(a) SODA:Ekman Advecive Heat Flux

(b) HYCOM:Ekman Advecive Heat Flux

(c) SODA:Ekman Currents & Temp

(d) HYCOM:Ekman Currents & Temp
Sea Surface Eddy Kinetic Energy ((cm/s)^2)

EKE = \frac{(u_{geo}^2 + v_{geo}^2)}{2}

(a) SODA

(b) HYCOM

(c) AVISO
Heat budget in the upper 50m (100W-80W, 30S-10S)

<table>
<thead>
<tr>
<th></th>
<th>HYCOM</th>
<th>SODA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface heat flux</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Geostrophic</td>
<td>-5</td>
<td>-9</td>
</tr>
<tr>
<td>Ekman</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Eddy flux div.</td>
<td>0.1</td>
<td>-0.1</td>
</tr>
</tbody>
</table>
Conclusions

Geostrophic transport in the upper 50m causes net cooling in most of the stratus cloud region

Ekman transport provides net warming north of the IMET site and net cooling south of the IMET site

The eddy heat flux divergence term can be comparable to other terms at a particular location such as the IMET site, but it is negligible for the entire stratus region when area averaged since it is not spatially coherent in the open ocean.

Surface buoy observations in locations both north and south of the IMET site would be useful.