Using A-Train Observations to Evaluate Ice Water Path and Ice Cloud Radiative Effects in the Community Atmosphere Model

Betsy Berry and Jay Mace, University of Utah

**Motivation**
- Large differences exist between modeled cloud ice and observations (Li et al., 2012)
- Yet models show consensus for a positive high cloud feedback (Vecchi and Soden, 2011)
- Examine cloud radiative effects as a function of Ice Water Path (IWP)
- Which type of cirrus contribute most to heating the upper troposphere?
- Use A-Train satellite data to evaluate ice clouds in a global climate model

**Data and Methods**
- Focus on region of Southeast Asia during monsoon season (August + September 2007-2008)
- Geometric cloud layers identified by combined radar-lidar mask (Mace et al, 2009)
- Multiphase algorithm suite (CloudSat, MODIS, AMSRE) to derive the liquid cloud microphysical properties (Mace, 2010)
- Ice microphysical properties from the CloudSat/CALIPSO 2C-ICE dataset (Deng et al., 2010)
- Radiative properties are calculated using existing parameterizations.
- Rapid Radiative Transfer Model (RRTM; Mlawer et al., 1997)
- Outputs: profiles of shortwave and longwave fluxes

**A-Train Results**

Use idea of cloud radiative kernels (Zeilinza et al., 2012a) to examine the radiative impact of ice clouds at the Top Of Atmosphere (TOA)

**Preliminary Model Analysis**

Examine ice clouds in Community Atmosphere Model Version 5 (CAM5)
- Output from 2005-2008 global run with 30 vertical levels and a 96x144 horizontal grid (~1.9° latitude x 2.5° longitude)
- 2-moment bulk stratiform cloud microphysics scheme (Morrison et al. 2005) with four hydrometeor species
- Process-based treatment of ice supersaturation and ice nucleation (Gettelman et al., 2010)

**Future Work**
- Calculate the radiative properties and run the radiative transfer for the model sub-columns in Southeast Asia
- Perform cloud radiative kernel analysis with CAM5
- How do modeled ice clouds differ from observed clouds?
- Do climate models show a similar distribution of cloud ice and radiative effect?
- Use output from CAM5, run in weather forecast mode (Xie et al., 2012), to see how quickly ice cloud biases develop

**Table 1. Characteristics of the most common cloud layers**

<table>
<thead>
<tr>
<th>Cloud Type</th>
<th>Top Height</th>
<th>Thickness</th>
<th>Occurrence</th>
<th>Mean IWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>T.T.L. Cirrus</td>
<td>&gt;14 km</td>
<td>&lt; 3 km</td>
<td>11%</td>
<td>6 gm^-2</td>
</tr>
<tr>
<td>Thin Cirrus</td>
<td>10-14 km</td>
<td>&lt; 3 km</td>
<td>13%</td>
<td>13 gm^-2</td>
</tr>
<tr>
<td>Thick Cirrus</td>
<td>&gt;10 km</td>
<td>3-6 km</td>
<td>23%</td>
<td>64 gm^-2</td>
</tr>
<tr>
<td>Deep Layers</td>
<td>&gt;10 km</td>
<td>&gt;6 km</td>
<td>34%</td>
<td>74 gm^-2</td>
</tr>
</tbody>
</table>

**Figures**

- Fig. 1: A typical cloud scene in the analysis region
- Fig. 2: Sensitivity of TOA fluxes to perturbations in cloud fraction (K)
- Clouds with the highest cloud top and moderate IWP (25-90 gm^-2) produce the strongest warming effect at TOA
- For cirrus clouds with IWP > 225 g m^-2, solar effects begin to dominate over the IR effects and clouds produce net cooling
- Fig. 3: Cloud fraction (C) as a function of CTP and IWP
  - Cloud fraction decreases with increasing IWP bins
  - Mean IWP = 440 g m^-2
  - 87% of profiles are not precipitating/convective
  - median IWP = 16 g m^-2
  - “cloud mode” represents 34% of total ice mass
  - 13% of profiles are precipitating/convective
  - median IWP = 1394 g m^-2
  - “precip mode” represents 66% of total ice mass
- Fig. 4: Contribution of each cloud type to TOA radiation (R), where R = K°C
  - TOA Net Cloud Radiative Effect (CRE) from cirrus = 17 W m^-2
  - Cirrus with IWP between 3 - 90 g m^-2 contribute most to heating given their frequency
  - Sum of TOA net CRE (-11 W m^-2) indicates a near balance between commonly occurring cirrus that warm the atmosphere and less frequent deep layers that produce strong cooling at the surface.
- Due to skewed IWP distribution, the median IWP is a better diagnostic of the radiative impact for cirrus clouds than the mean IWP

**Figures**

- Fig. 5: Thermodynamic and cloud microphysical variables from a CAM5 grid box (latitude: 12.32°, longitude: 102.5°) in our study domain at 12Z on August 1, 2007.
- Fig. 6: Generated sub columns of cloud microphysical properties for the grid box data shown in Fig. 7.