Application of the CERES Flux-by-Cloud Type Simulator to GCM Output

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What is the Flux-by-cloud type product?

- Assigns a flux to each observed ISCCP cloud type within a region.
- For each 1°x1° region between 60° S and 60° N, each daytime footprint is placed into 1-3 $p_c-\tau$ ISCCP-like categories (3 categories would be the case of a footprint with two cloud levels as well as clear pixels).
- For the footprints with a single cloud type, the standard SSF flux is added to that $p_c-\tau$ category.
- For footprints with multiple cloud levels, narrowband-to-broadband radiance conversions are performed for each cloud level.
- Broadband radiances are converted to fluxes using ADMs.
What is a simulator?

- Put simply, a simulator is meant to replicate what a space-based instrument would measure if it flew above a GCM or other model on the temporal and spatial scales of the measurements.
Motivation for flux-by-cloud type simulator

- Cloud properties and fluxes/albedos will be matched within 1.5 hours to the closest CERES overpass, which is important because of the large diurnal cycles in cloud fraction, $\tau$, and $p_c$ in many areas.
- Breaking out the flux by cloud type can help isolate physical parameterizations that are problematic (e.g., convective clouds, boundary-layer parameterizations, or processes involving surface albedo), and provide a test for new parameterizations.
- Diagnoses using flux-by-cloud type combined with frequency of occurrence can also help determine whether an unrealistically small or large occurrence of a given cloud type has an important radiative impact for a given region.
Outline of Simulator Approach

1. Read in data at GCM grid size
2. Run cloud generator to produce 1000 atmospheric subcolumns per grid cell
3. Use cloud property simulator to classify subcolumns into $p_c-\tau$ cloud types
4. Perform radiative transfer on every subcolumn in each type to get fluxes
Outline of *Faster* Simulator Approach

1. Read in data at GCM grid size
2. Run cloud generator to produce 1000 subcolumns per grid cell
3. Many subcolumns are identical. Find number of unique profiles.
4. Use cloud property simulator to classify subcolumns into $p_c$-$\tau$ cloud types
5. Perform radiative transfer on each unique subcolumn in each type to get fluxes

Number of RT calculations needed now depends on how much variety of clouds there is in a given grid box, but for the three regions here, the number of calculations is reduced by 95-99%.
SW Flux consistency check (Simulator- HadGEM2-A):
Subcolumns reproduce GCM grid-scale SW fluxes fairly well
LW Flux consistency check: Simulator has negative biases, especially over Eq Pacific. RMS errors are mainly due to biases.
Southeast Pacific results

Image from Strebe, https://commons.wikimedia.org/wiki/File:Mercator_projection_SW.jpg
Cloud fraction (%) for CERES, HadGEM2-A over SE Pacific (Jan 2008)

HadGEM2-A – CERES. Good general pattern, but too many low, thick clouds and not enough low, thin clouds.

Grid-mean total cloud fraction:
CERES: 0.578
HadGEM2-A: 0.475
TOA SW albedo by cloud type for CERES, HadGEM2-A over SE Pacific (Jan 2008)

Grid-mean all-sky SW albedo:
CERES: 0.193
HadGEM2-A: 0.189
TOA LW flux by cloud type (W m\(^{-2}\)) for CERES, HadGEM2-A over SE Pacific (Jan 2008)

HadGEM2-A – CERES. OLRs are low for most cloud types, but too high for some high- and medium-top clouds.

Grid-mean all-sky OLR:
CERES: 272.4 W m\(^{-2}\)
HadGEM2-A: 275.5 W m\(^{-2}\)
Equatorial Pacific results

Image from Strebe, https://commons.wikimedia.org/wiki/File:Mercator_projection_SW.jpg
Cloud fraction (%) for CERES, HadGEM2-A over Equatorial Pacific (Jan 2008)

HadGEM2-A – CERES. Far too few clouds overall, especially for high, thin clouds.

Grid-mean total cloud fraction:
CERES: 0.798
HadGEM2-A: 0.397
TOA SW albedo by cloud type for CERES, HadGEM2-A for Equatorial Pacific (Jan 2008)

HadGEM2-A – CERES. Albedos a bit low for most cloud types, but high for medium/high optical depths at lower altitudes.

Grid-mean all-sky SW albedo:
CERES: 0.220
HadGEM2-A: 0.186
TOA LW flux by cloud type (W m\(^{-2}\)) for CERES, HadGEM2-A over Equatorial Pacific (Jan 2008)

HadGEM2-A – CERES. OLRs are low for almost all cloud types, except for highest, thinnest clouds.

Grid-mean all-sky OLR:
- CERES: 227.7 W m\(^{-2}\)
- HadGEM2-A: 260.2 W m\(^{-2}\)
Southern Great Plains results

Image from Strebe, https://commons.wikimedia.org/wiki/File:Mercator_projection_SW.jpg
Cloud fraction (%) for CERES, HadGEM2-A over Southern Great Plains (Jan 2008)

HadGEM2-A – CERES. Similar amounts of clouds for most types, but more high clouds than observed.

Grid-mean total cloud fraction:
- CERES: 0.539
- HadGEM2-A: 0.518
TOA SW albedo by cloud type for CERES, HadGEM2-A for Southern Great Plains (Jan 2008)

HadGEM2-A – CERES. Albedos low for most cloud types, especially at mid-levels.

Grid-mean all-sky SW albedo:
CERES: 0.367
HadGEM2-A: 0.330
TOA LW flux by cloud type (W m$^{-2}$) for CERES, HadGEM2-A over SGP (Jan 2008)

HadGEM2-A – CERES. OLRs are too high for most low, medium height clouds.

Grid-mean all-sky OLR:
CERES: 231.1 W m$^{-2}$
HadGEM2-A: 240.3 W m$^{-2}$
• Identifying unique subcolumns reduces the number of RT calculations required by >95%.

• SW biases and RMS errors between the RT model and HadGEM2-A are relatively small, but there is a negative bias in OLRs.

• Over the SE Pacific, HadGEM2-A produces low clouds and has a realistic all-sky albedo, but the clouds tend to be too few and too thick.

• Over the Equatorial Pacific, HadGEM2-A produces far too few clouds, resulting in unrealistically high all-sky OLR, even though the OLR by cloud type is generally low.

• Over the Southern Great Plains, the cloud fraction is realistic, with clouds generally in the right place, but albedo is too low and OLR is too high, possibly indicating a problem with (too little) snow cover?