Flux by Cloud Type (FluxByCldTyp) Monthly Product

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Flux by Cloud Type (FluxByCldTyp) Data

A daytime dataset that stratifies CERES observed fluxes and MODIS cloud properties from the SSF data into 42 cloud type bins based on cloud optical depth (tau) and cloud effective pressure.

Motivation: To provide the community a data set with both radiative fluxes and cloud properties by cloud type for modeling and observational studies.
CERES SSF Footprint Structure

- CERES footprint size: 20km nadir
- The footprint is divided into Clear, Cloud Layer 1, Cloud Layer 2 areas (sub-footprint), based on MODIS pixel level (2km resolution) cloud properties
- CERES observed flux encompasses entire footprint containing up to 3 sub-footprint areas
- Each sub-footprint has MODIS radiances and cloud properties but NO flux

**Aim:** To obtain flux for each of the three sub-footprint areas: clear, lower cloud and upper cloud.
Algorithm

- Derive Daytime Narrowband to Broadband Radiance Model (NB2BB) using single (uniform) scene footprints
- Apply NB2BB Radiance Model to sub-footprint MODIS NB radiance to obtain BB radiance
- Convert Sub-footprint BB radiance to Flux by applying the Ed4 ADM (Angular Distribution Model)
- Constrain Sub-footprint Fluxes by the footprint-level flux (Normalization)
- Sort fluxes and cloud properties into 42 cloud types based on Pressure/Tau and grid them into 1° x 1° region to produce FluxByCldTyp-hourly product
- Obtain FluxByCldTyp-monthly product by temporally averaging the data
Narrowband to Broadband Radiance Model
Daytime (NB2BB)

SSF Criteria:
Footprints with only one sub-footprint type, either (0%) or (>=99.9%) overcast single layer

Define bin (category):
- SW (SZA <= 90)
  - SZA(9): 0-90, every 10
  - VZA(7): 0-70, every 10
  - RAZ(9): 0-180, every 20
- LW
  - VZA(7): 0-70, every 10
  - PW(4) : (0,1,3,5,10)
- 7 Surface Types: Ocean, Land (Forests, Savannas, Grass/Crop, Dark Deserts, Bright Deserts, Snow/Ice)

All MODIS NB Channels on SSF cloud layers and clear area are used:
- SW: 0.47, 0.65, 0.86, 11, 12 (um)
- LW: 0.47, 0.65, 0.86, 11, 12 (um)

\[ \text{BBrad} = a_0 + a_1 \times \text{Rad1} + a_2 \times \text{Rad2} + a_3 \times \text{Rad3} + a_4 \times \text{Rad4} + a_5 \times \text{Rad5} \]
Sub-footprint Broadband Radiance to Flux - Applying the Ed4 ADM

ADM (Angular Distribution Model) is based on angles, cloud amount, optical depth, surface type and applied to each sub-footprint MODIS derived BB radiance

The sub-footprint fluxes are used to compute the footprint flux and compared with the CERES observed flux to scale the sub-footprint fluxes to match the CERES flux (Normalization)
FluxByCldTyp Algorithm

1. SSF Footprints
2. NB2BB: clear/cld1/cld2
3. BB2Flx: clear/cld1/cld2
4. Sort clouds/flux into ISCCP-D1 cloud types
5. Grid into 1° x 1°
6. Write FluxByCldTyp-hour
7. Write monthly

NB2BB coefficients
ADM Ed4
Monthly Mean Methodology

Convert Instantaneous fluxes into monthly mean fluxes:

- Convert all instantaneous fluxes during one day into a daily mean flux
  - Convert the SW instantaneous flux into a SW Equivalent Daily Mean Flux
- Convert the daily mean fluxes into a monthly mean flux
  - Take into account the regional daily solar flux variation by deriving monthly mean SW based on monthly mean albedo and monthly solar insolation (Solar Weighting)
SW Equivalent Daily Mean Flux

- SW Equivalent daily mean flux is 24hr daily mean flux based on instantaneous observation and scene based directional model that assumes the same meteorology condition for the whole day.
- The equivalent daily mean flux is the 24-hour integrated area under the SW flux curve.
The 1-step method is not consistent with the temporal average of the SSF1deg product. The 1-step averaging is dependent on sampling variations.
### Monthly Mean Methodology (2-step)

**obs -> daily -> monthly flux (used by FBCT)**

**Formulae**

\[
Flux_d = \frac{\sum_{h=1}^{N_d} Flux_h \cdot f_h}{\sum_{k=1}^{N} f_h}
\]

\[
Flux_m = \frac{\sum_{d=1}^{ND} Flux_d \cdot f_d}{\sum_{d=1}^{N} f_d}
\]

The FBCT 2-step product is consistent with the temporal interpolation of the SSF1deg product.

The 2-step averaging is better suited to handle sampling variations.
Solar Weighting: Monthly mean RSW

- The monthly mean SW is derived from monthly mean albedo and mean solar insolation
- RSW (Reflected SW) monthly mean is derived for each cloud type and for clear sky:

\[
\alpha_m = \frac{\sum_{d=1}^{N} RSW_d \cdot f_d}{\sum_{d=1}^{N} S_d \cdot f_d} \quad N = \# \text{ days of available SW}
\]

\[
S_m = \frac{1}{N_{max}} \sum_{d=1}^{N_{max}} S_d \quad N_{max} = \# \text{ all days in a month}
\]

\[
RSW_m = \alpha_m \cdot S_m
\]

Impact depends on number of missing daily observations in a month
Validation

• Validate the FBCT-month product by comparing to SSF1Deg-Lite (Terra+Aqua Merge)

• Derive total flux from all 42 cloud type and clear-sky fluxes for the month and compare to the all-sky monthly mean

Note: foot-print level and hourly grid level data validation were presented before
The FBCT product does not contain night time LW fluxes, because the night time clouds (based only on IR channels) are not of the same quality as day time (based on IR and visible channels).

<table>
<thead>
<tr>
<th></th>
<th>FBCT-month</th>
<th>SSF1Deg-Lite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporal interpolation</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>LW</td>
<td>Day only obs</td>
<td>Day and Night obs</td>
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<tr>
<td>Clear-sky</td>
<td>Sub-footprint + footprint</td>
<td>Footprint only</td>
</tr>
<tr>
<td>SZA limit</td>
<td>SZA ≤ 86.5</td>
<td>SZA ≤ 90</td>
</tr>
<tr>
<td>Twilight</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Adjust to center hr box</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Validation: SW All-Sky, Terra+Aqua, Jan. 2010
FluxByCldTyp minus SSF1deg-Lite

SSF1Deg-Lite Mean

FBCT minus Lite

FBCT 2-step minus Lite

FBCT 1-step minus Lite
Validation: SW Clear, Terra+Aqua, Jan. 2010
FluxByCldTyp minus SSF1deg-Lite

SSF1Deg–Lite

FBCT minus Lite

FBCT Mean

FBCT 1-step minus Lite
Validation: LW All-Sky, Terra+Aqua, Jan. 2010
FluxByCldTyp minus SSF1deg-Lite

SSF1Deg-Lite

FBCT 2-step minus 1-step

FBCT 2-step minus Lite

FBCT 1-step minus Lite
Validation: LW Clear, Terra+Aqua, Jan. 2010
FluxByCldTyp minus SSF1deg-Lite

**SSF1Deg-Lite**

201001 LWcIrr(W/m²) Mean: SSF1deg-Month

**FBCT: 2-step minus 1-step**

201001 LWcIrr(W/m²) Mean Diff: 2-step QC - 1-step QC

**FBCT 2-step minus Lite**

201001 LWcIrr(W/m²) Diff: FlxByCld 2-step - SSF1deg Lite

**FBCT 1-step minus Lite**

201001 LWcIrr(W/m²) Diff: FlxByCld 1-step - SSF1deg Lite
Example: Tropical Western Pacific
Mean 2003.03-2015.09

Cloud Fraction

SWCRF

LWCRF
CERES FluxByCloudTyp Product

- MODIS imager radiances
  - MODIS cloud retrievals
    - Cloud freq
      - CERES-MODIS cloud occurrence frequency (%)
        - p_c,τ
      - Evaluate
    - Generate subcolumn clouds at overpass time
      - Cloud freq
        - p_c,τ
      - Evaluate
    - Get Langley Fu-Liou radiative transfer model fluxes
      - OLR by cld typ
        - CERES TOA LW flux (W/m²) by cloud type
          - p_c,τ
        - Evaluate
    - OLR by cld typ
      - CERES TOA LW flux (W/m²) by cloud type
        - p_c,τ
        - Evaluate

CERES Flux-by-cloud Type Simulator

- CFMIP 3-hourly gridded output
  - Generate subcolumn clouds at overpass time
  - Get Langley Fu-Liou radiative transfer model fluxes
  - OLR by cld typ
  - Evaluate

CERES FluxbyCldTyp Simulator by Eitzen et al.

- MODIS imager radiances
  - MODIS cloud retrievals
  - Cloud freq
    - CERES-MODIS cloud occurrence frequency (%)
      - p_c,τ
    - Evaluate
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Summary

- The Ed4 FluxByCldTyp algorithm is developed and preliminary validation and results are shown.
  - The monthly mean algorithm was designed to be consistent with other TISA averaged products.
  - The entire record will be validated before delivery.
- Code delivery to production is expected in summer. The product will be released in fall.
Thank you!

For more information:
https://ceres.larc.nasa.gov/