Flux by Cloud Type (FluxByCldTyp) Monthly Product

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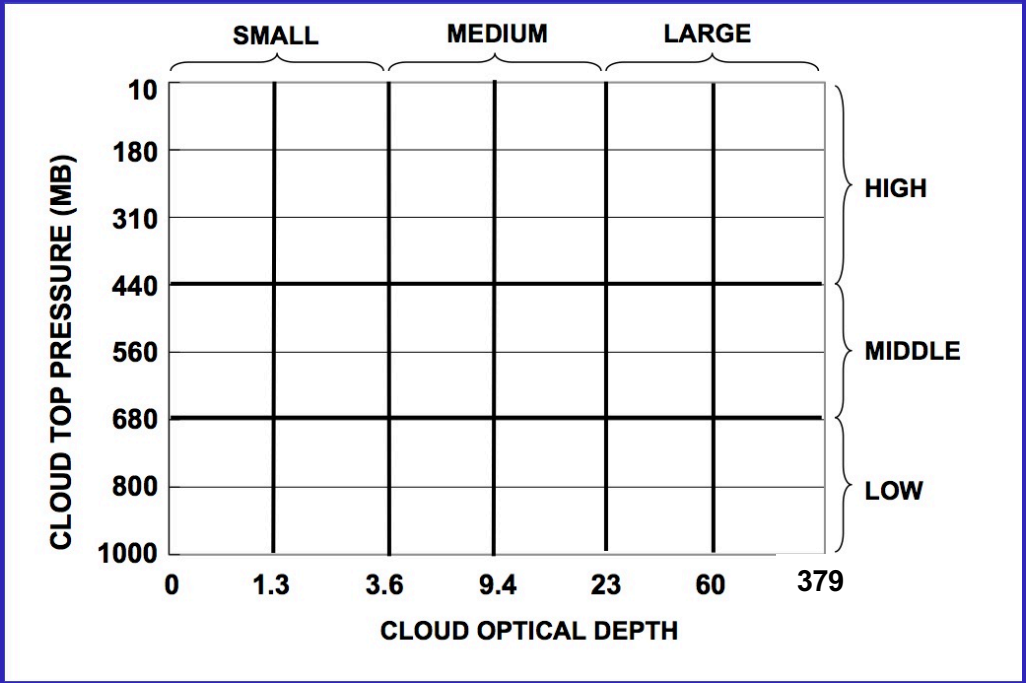
CERES Science Team Meeting

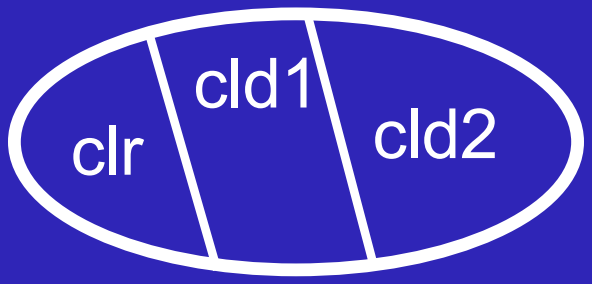
NASA Langley, May 7, 2019

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



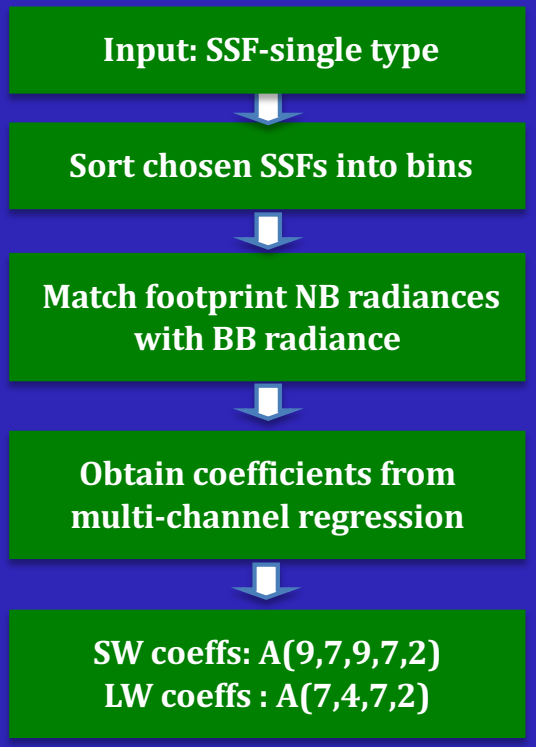
- CERES footprint size: 20km nadir
- The footprint is divided into Clear, Cloud Layer 1, Cloud Layer 2 areas (sub-footprint), based on MODIS pixel level (2km resolution) cloud properties
- CERES observed flux encompasses entire footprint containing up to 3 sub-footprint areas
- Each sub-footprint has 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^{o} x 1^{o} 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)
- **BBrad = a0 + a1*Rad1 + a2*Rad2 + a3*Rad3 + a4*Rad4 + a5*Rad5**

Sub-footprint Broadband Radiance to Flux - Applying the Ed4 ADM

CERES-like BB

BB Radiance (*I*)

↓

CERES Ed4 ADM

↓

BB Flux (*F*)

↓

Flux Constraint (next slide)

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)

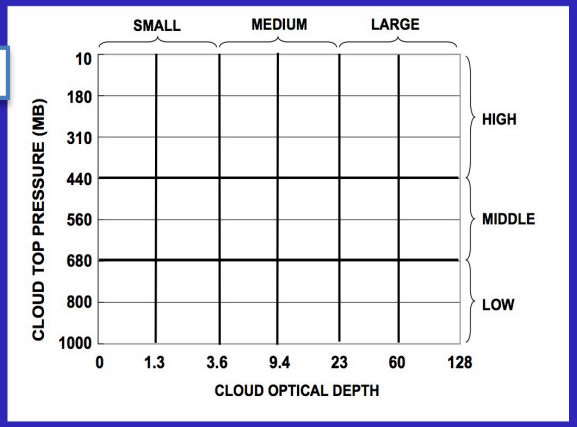
FluxByCldTyp Algorithm

SSF Footprints

NB2BB: clear/cld1/cld2 ← NB2BB coefficients

BB2Flx: clear/cld1/cld2 ← ADM Ed4

Sort clouds/flux into ISCCP-D1 cloud types



Grid into 1^0 x 1^0

Write FluxByCldTyp-hour

Write monthly

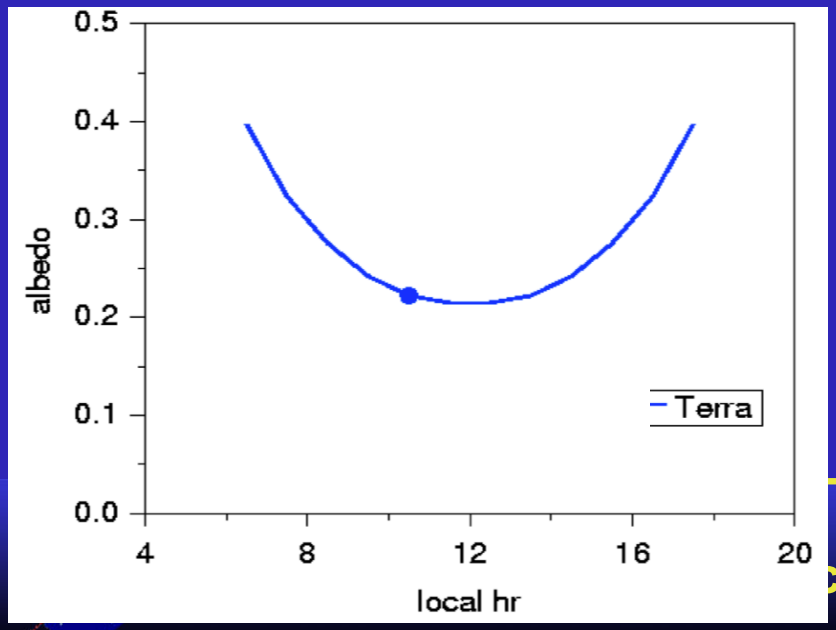
Monthly Mean Methodology

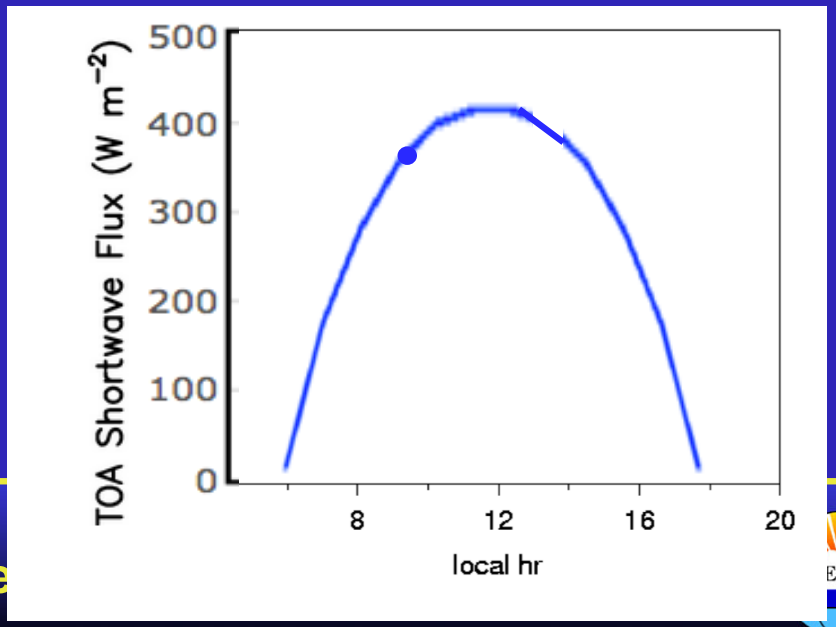
Convert Instantaneous fluxes into monthly mean fluxes:

- 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

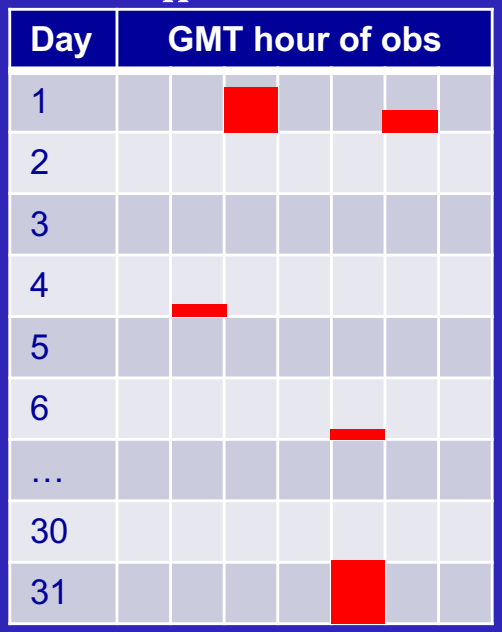
- SW Equivalent daily mean flux is 24hr daily mean flux based on instantaneous observation and scene based directional model that assumes the same meteorology condition for the whole day
- The equivalent daily mean flux is the 24-hour integrated area under the SW flux curve

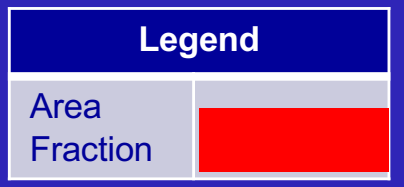




Monthly Mean Methodology (1-step) obs -> monthly flux (NOT used by FBCT)

f_h *(weighting)*





$$Flux_m = \frac{\sum_{h=1}^{N} Flux_h * f_h}{\sum_{k=1}^{N} f_h}$$

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)

f_h *(weighting)*

Day	GMT hour of obs
1	
2	
3	
4	
5	
6	
…	
30	
31	

f_d *(weighting)*

Day	
1	
2	
3	
4	
5	
6	
…	
30	
31	

Legend	
Area Fraction	

100 %

0

Monthly
Flux

$$f_d = \frac{\sum_{d=1}^{N_d} f_h}{N_d} \; daily\ area\ fraction$$

$$Flux_d = \frac{\sum_{h=1}^{N_d} Flux_h * f_h}{\sum_{k=1}^{N} f_h}$$

$$Flux_m = \frac{\sum_{d=1}^{ND} Flux_d * f_d}{\sum_{d=1}^{N} f_d}$$

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:

$$\alpha_m = \frac{\sum_{d=1}^{N} RSW_d * f_d}{\sum_{d=1}^{N} S_d * f_d}$$

N = # days of available SW

$$S_m = \frac{1}{N_{max}} \sum_{d=1}^{N_{max}} S_d$$

N_{max} = # 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

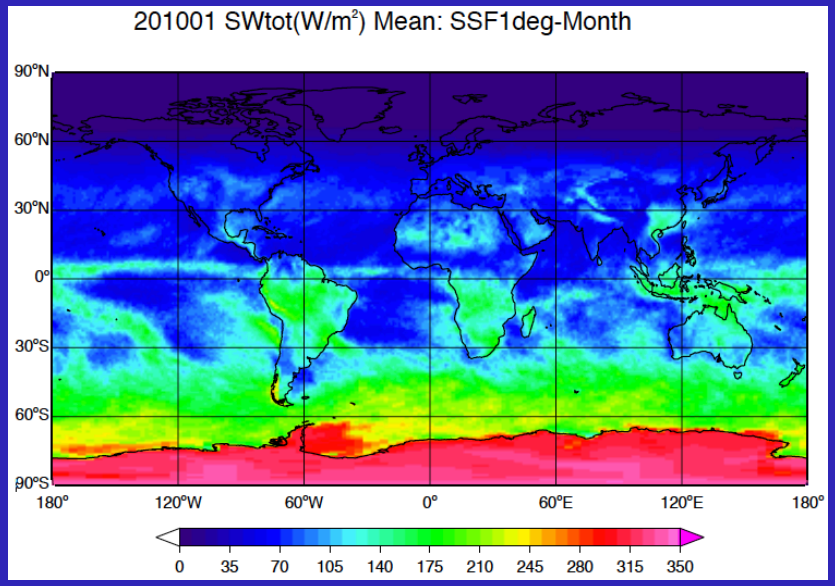
Difference Between FluxByCldTyp and SSF1DegLite

	FBCT-month	SSF1Deg-Lite
Temporal interpolation	No	Yes
LW	Day only obs	Day and Night obs
Clear-sky	Sub-footprint + footprint	Footprint only
SZA limit	SZA $\leq$ 86.5	SZA $\leq$ 90
Twilight	No	Yes
Adjust to center hr box	No	Yes

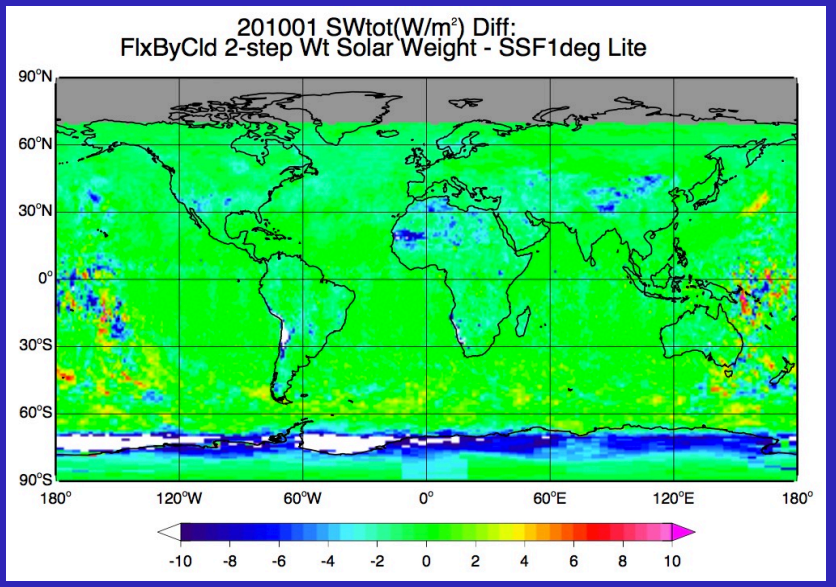
The FBCT product does not contain night time LW fluxes, because the night time clouds (based only on IR channels) are not of the same quality as day time (based on IR and visible channels).

Validation: SW All-Sky, Terra+Aqua, Jan. 2010
FluxByCldTyp minus SSF1deg-Lite

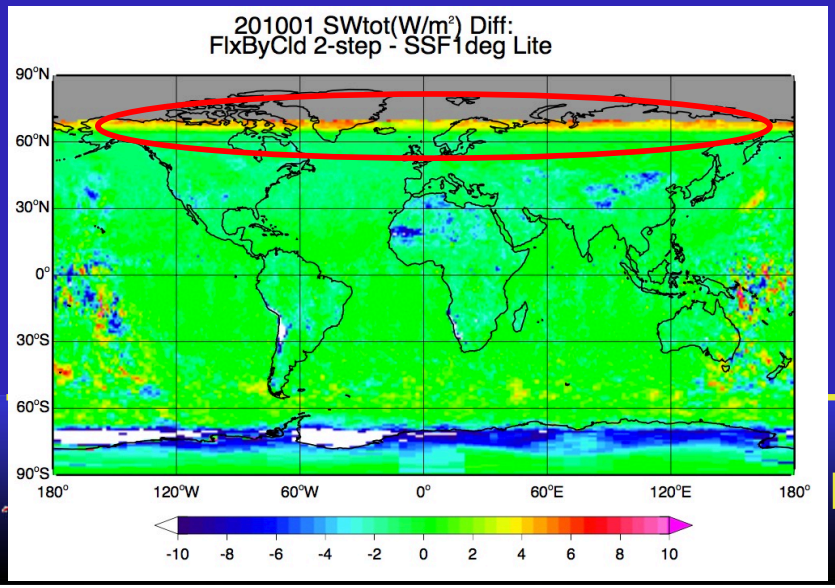
SSF1Deg-Lite Mean



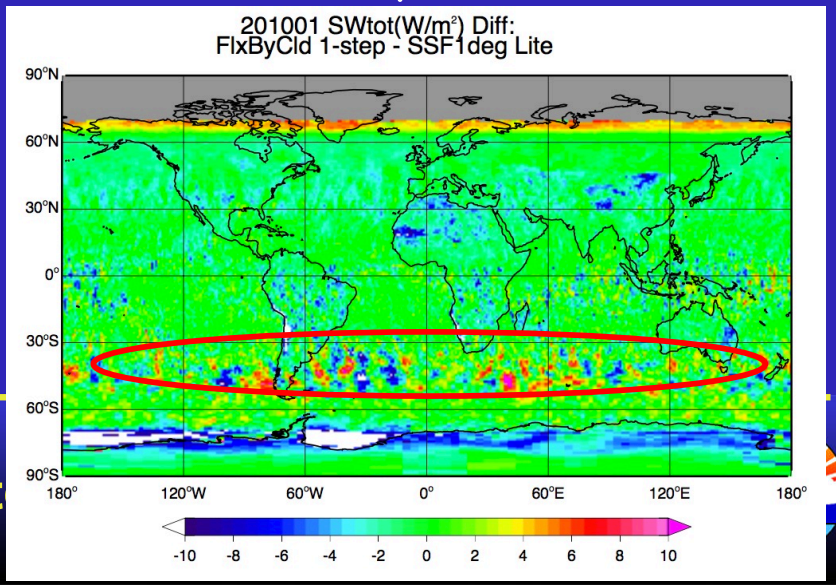
FBCT minus Lite



FBCT 2-step minus Lite

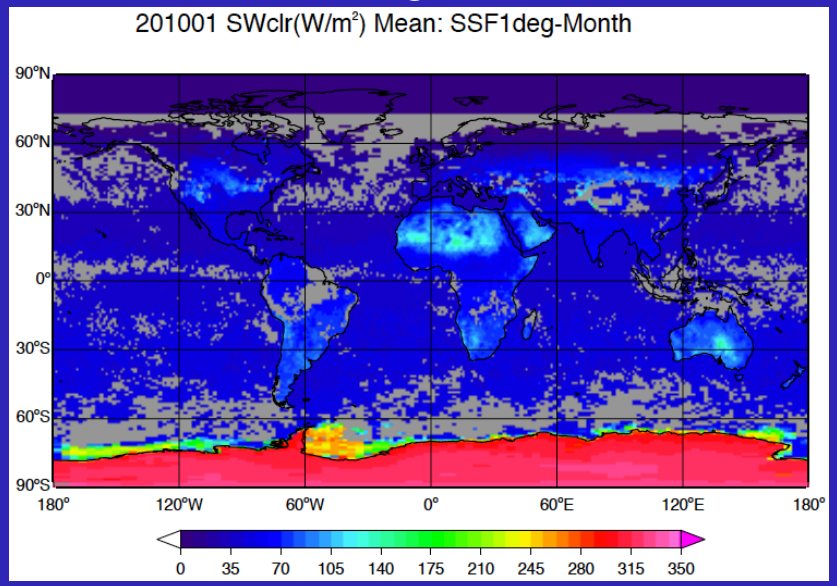


FBCT 1-step minus Lite

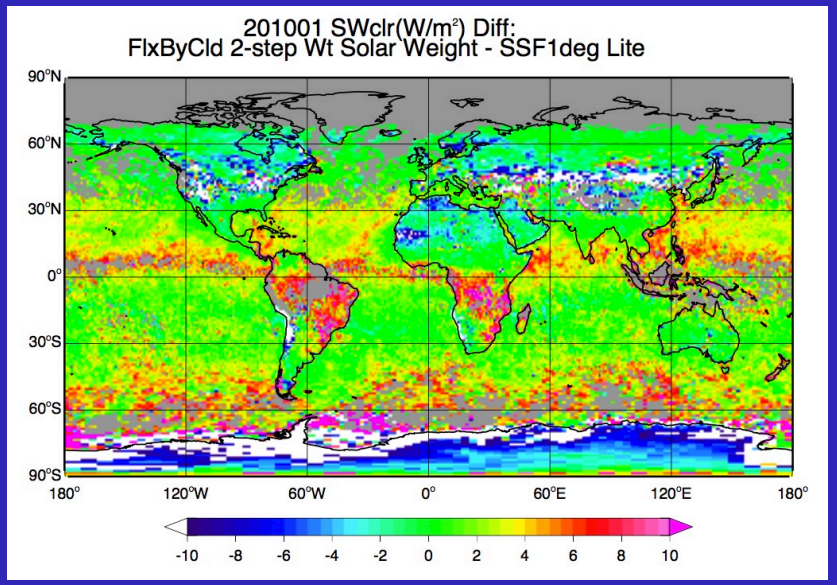


Validation: SW Clear, Terra+Aqua, Jan. 2010
FluxByCldTyp minus SSF1deg-Lite

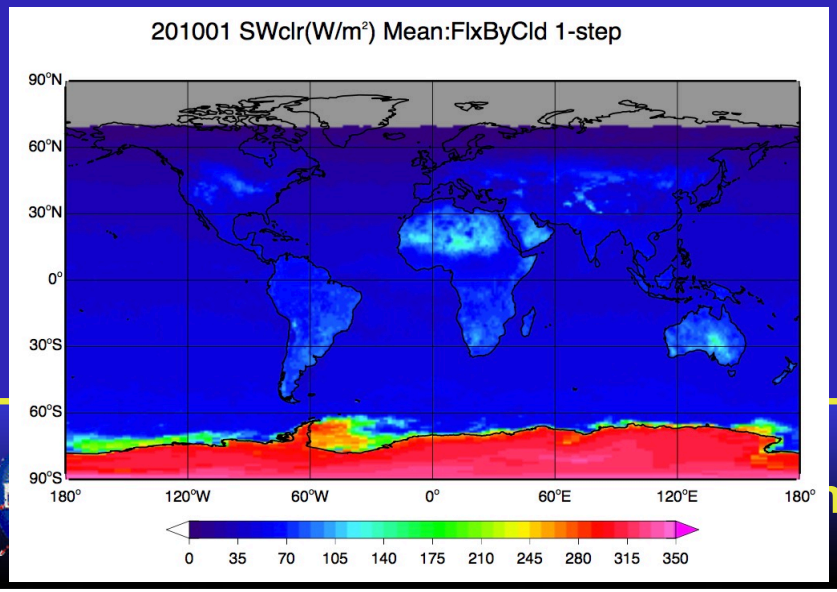
SSF1Deg-Lite



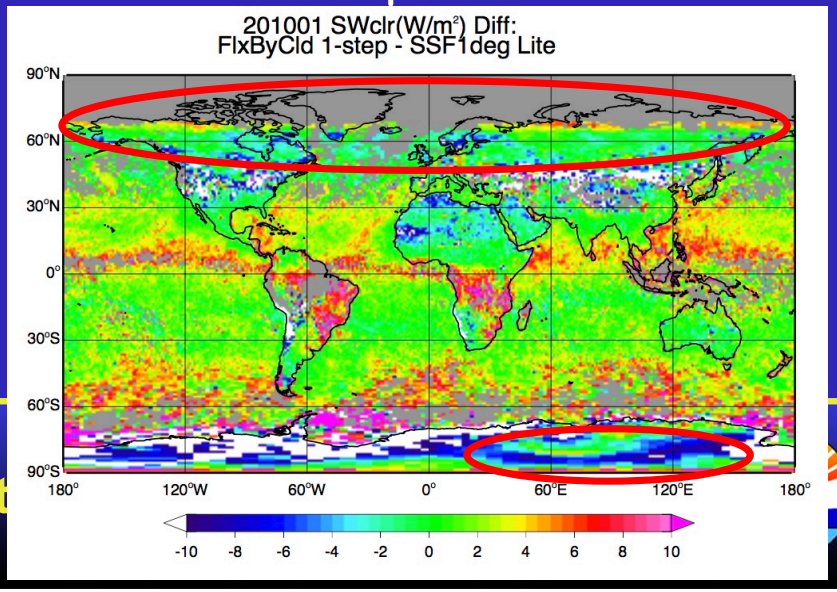
FBCT minus Lite



FBCT Mean

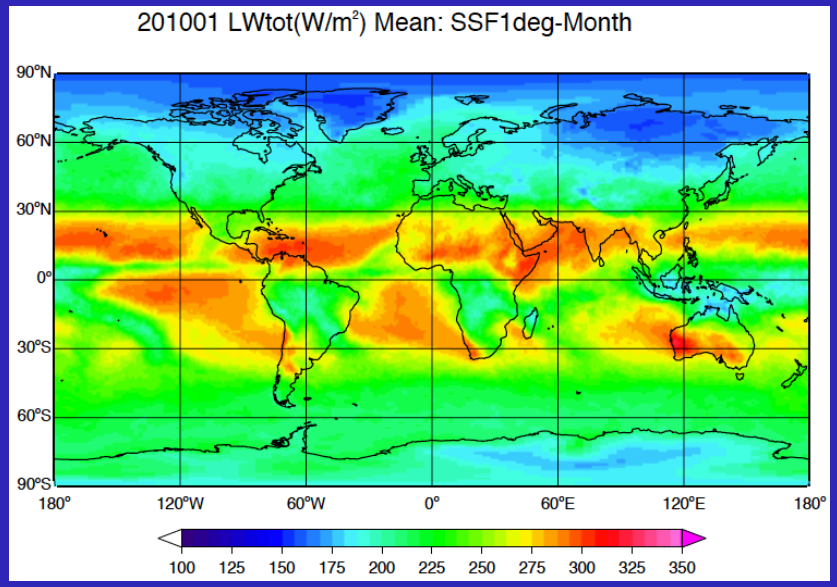


FBCT 1-step minus Lite

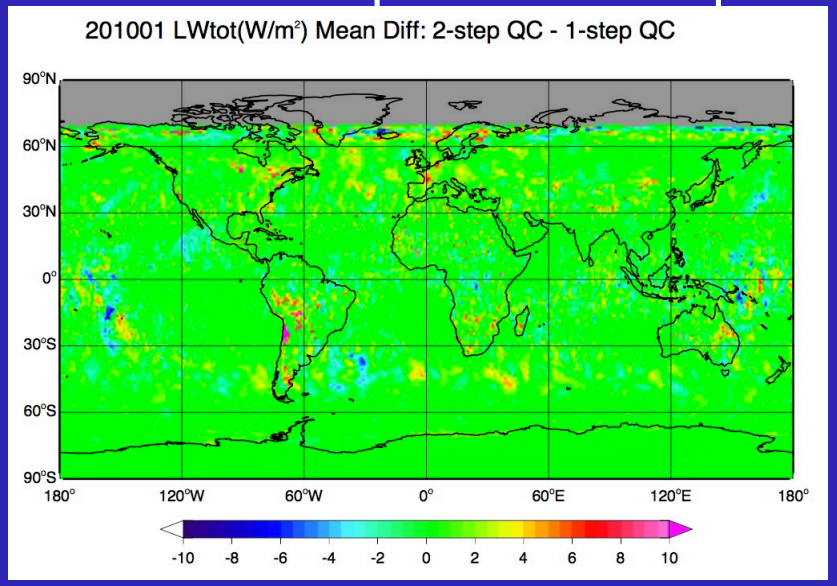


Validation: LW All-Sky, Terra+Aqua, Jan. 2010
FluxByCldTyp minus SSF1deg-Lite

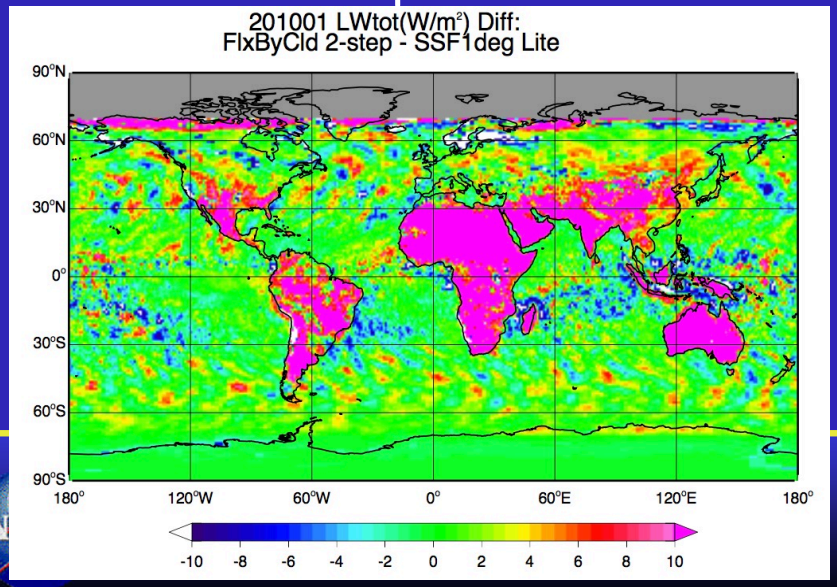
SSF1Deg-Lite



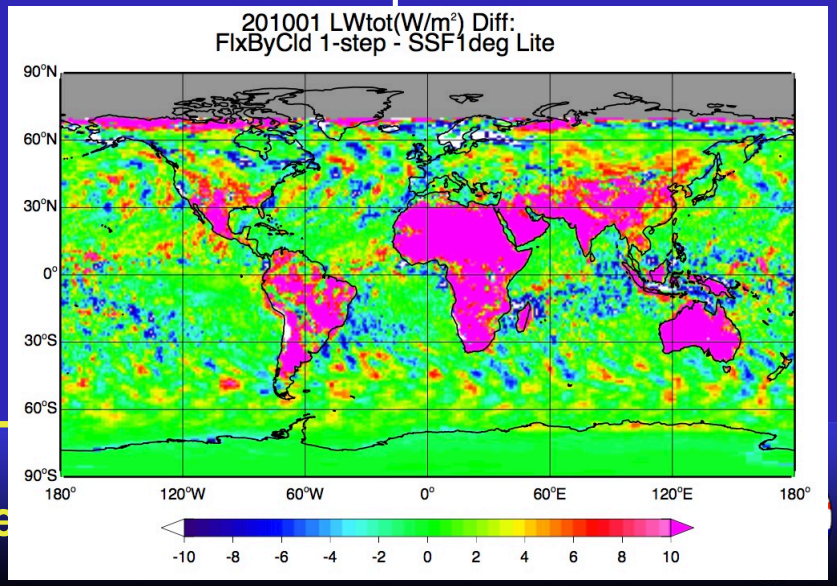
FBCT 2-step minus 1-step



FBCT 2-step minus Lite

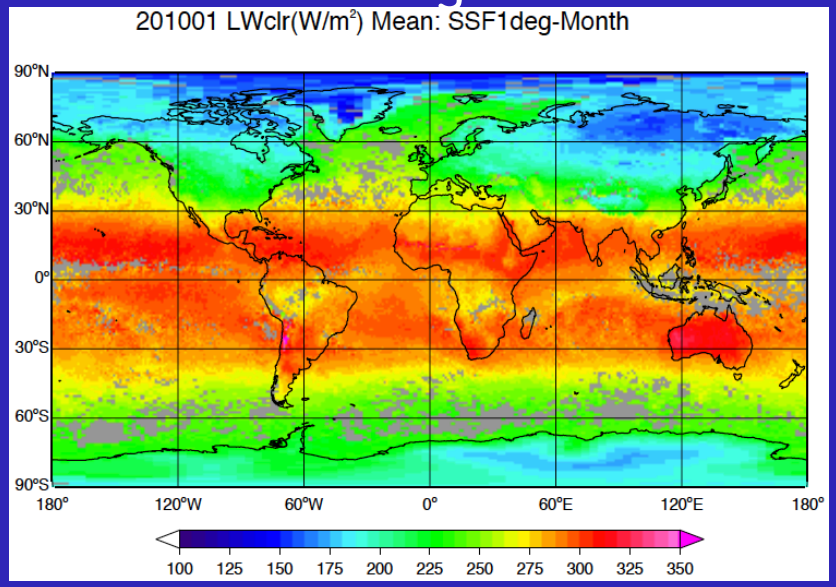


FBCT 1-step minus Lite

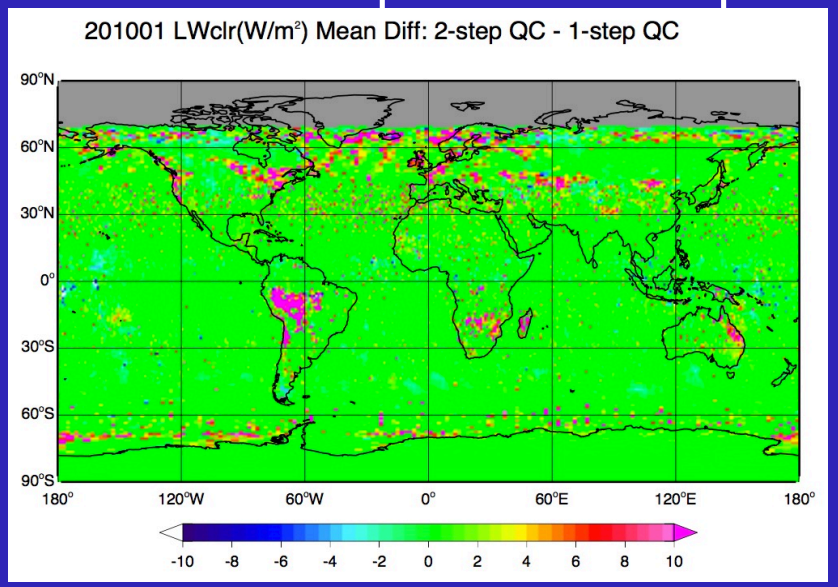


Validation: LW Clear, Terra+Aqua, Jan. 2010
FluxByCldTyp minus SSF1deg-Lite

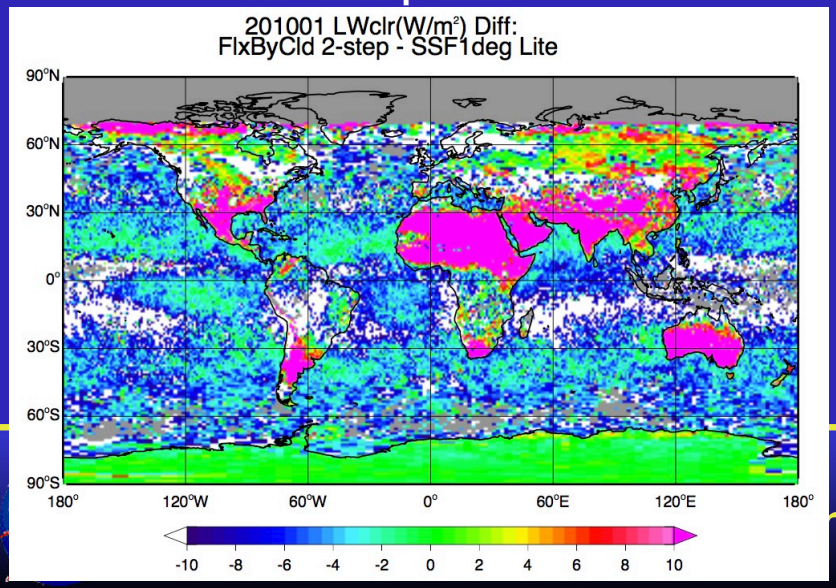
SSF1Deg-Lite



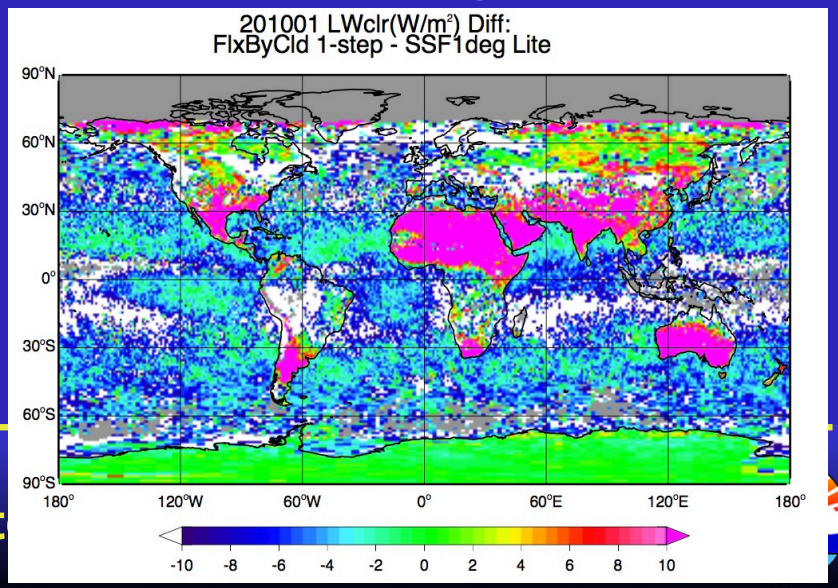
FBCT: 2-step minus 1-step



FBCT 2-step minus Lite

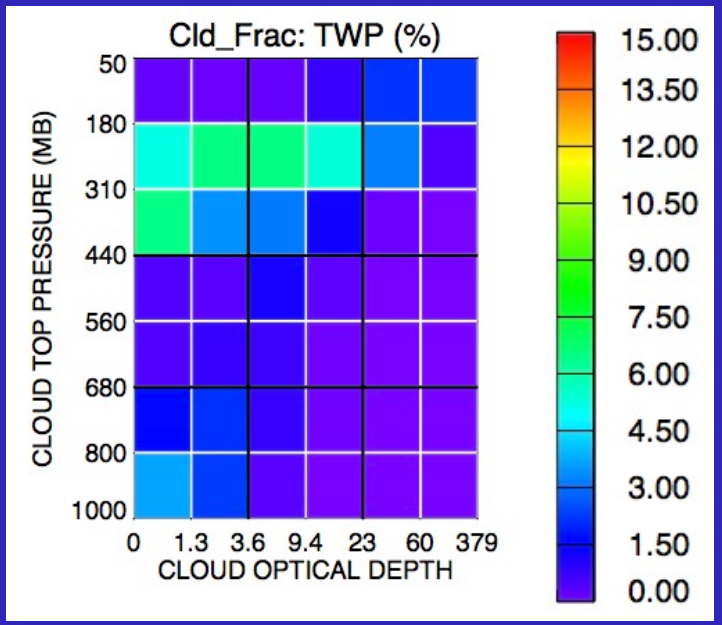


FBCT 1-step minus Lite

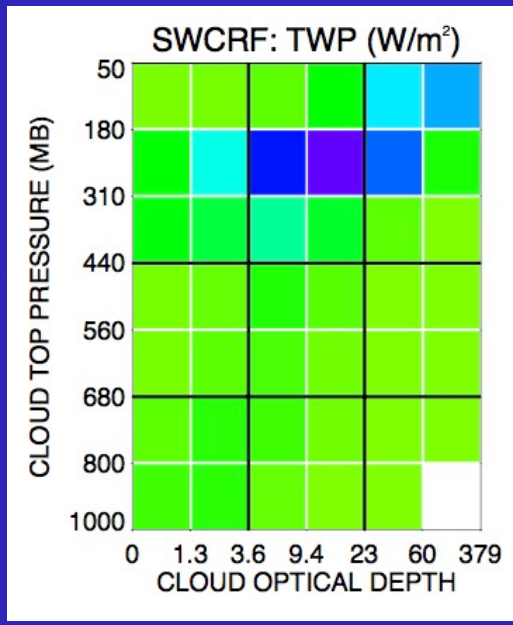


Example: Tropical Western Pacific Mean 2003.03-2015.09

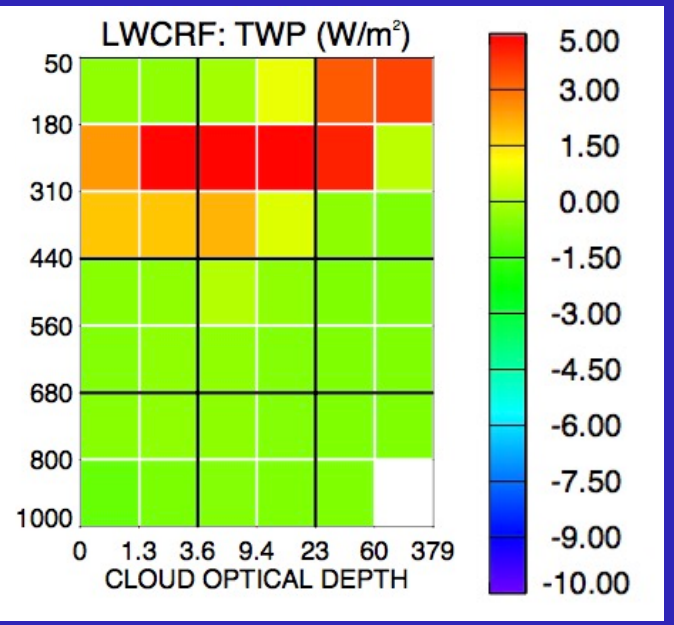
Cloud Fraction



SWCRF



LWCRF



CERES FluxByCloudTyp Product

CERES Flux-by-cloud Type Simulator

MODIS imager radiances

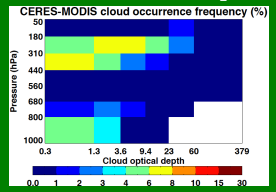
MODIS cloud retrievals

Generate subcolumn clouds at overpass time

CFMIP 3-hourly gridded output

Cloud freq

p_c



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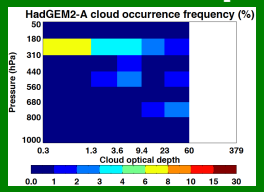
Evaluate

Cloud freq

p_c



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CERES FluxbyCldTyp Simulator by Eitzen et al.

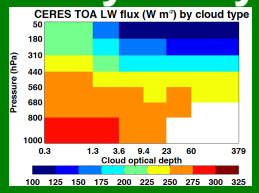
Get Langley Fu-Liou radiative transfer model fluxes

Grid box sfc alb, T, qv, O_3 profiles

CERES SSF clouds, fluxes

OLR by cld typ

p_c



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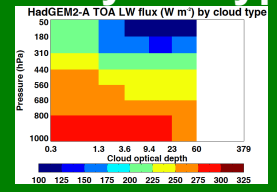
Evaluate

OLR by cld typ

p_c



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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/