Cloud Radiative Forcing of Deep Convective Systems Partitioned by A Hybrid Ground Radar and Satellite Objective Classification Technique

Zhe Feng (zhe.feng@und.edu), Xiquan Dong, and Baike Xi, University of North Dakota
Patrick Minnis and Mandana Khaiyer, NASA Langley Research Center

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Monday 2:40-4:00PM

Objective

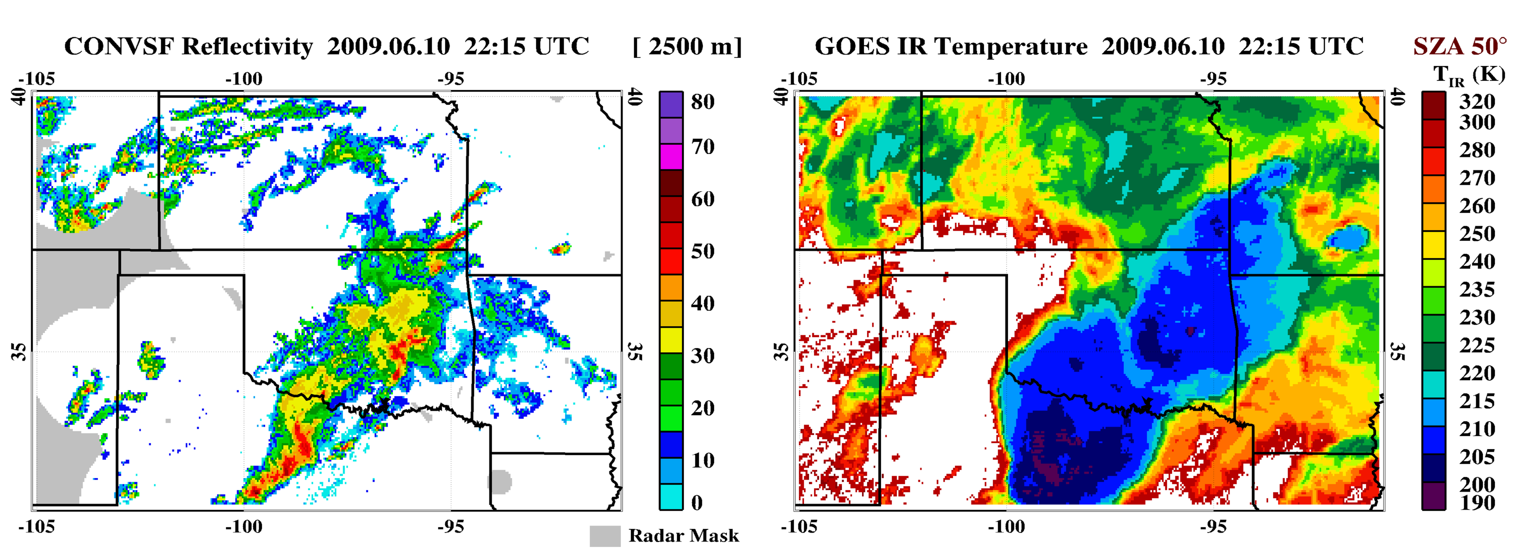
1. Develop an objective classification technique to identify Deep Convective Systems (DCS) and separate their rain core and associated anvil clouds using merged radar and GOES observations
2. Calculate Cloud Radiative Forcing (CRFs) of different cloud types within DCS (core, anvil) and quantitatively estimate their impact to the radiation budget

Dataset

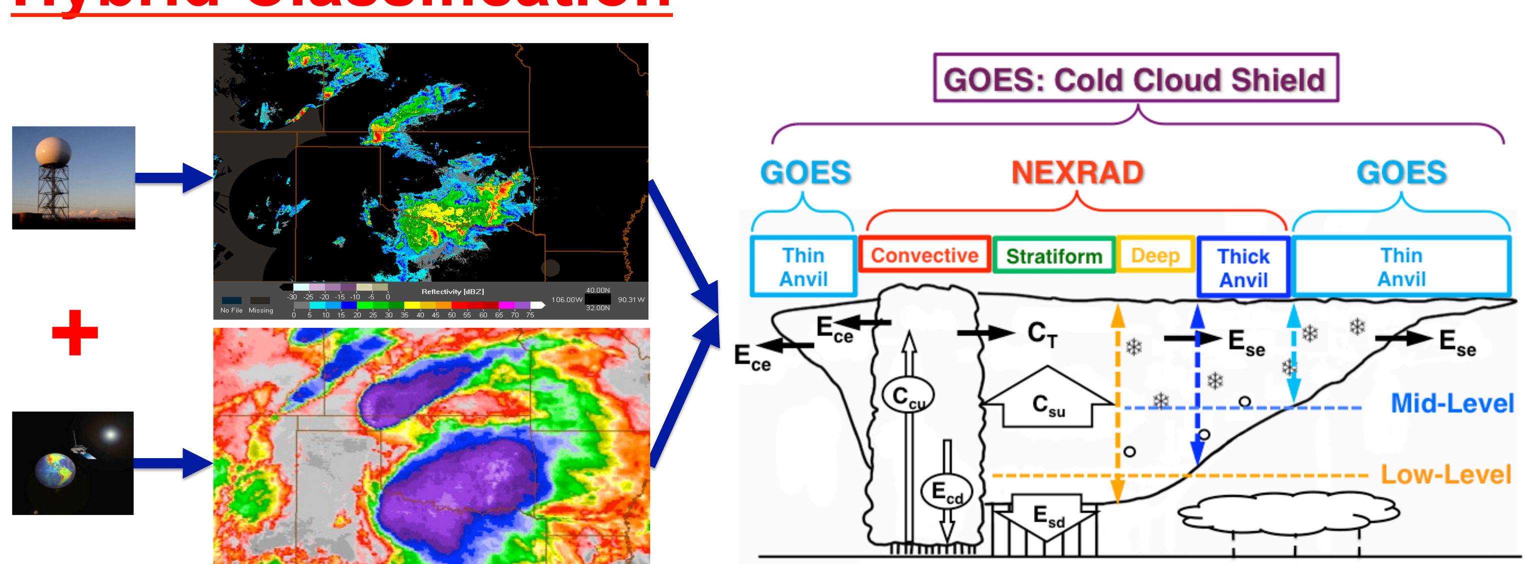
NEXRAD Q2 Product (NSSL)
- 3D Mosaic reflectivity in Southern Great Plane (SGP) region (8×15°)

GOES Cloud Product (NASA Langley)
- Pixel-level cloud property retrievals

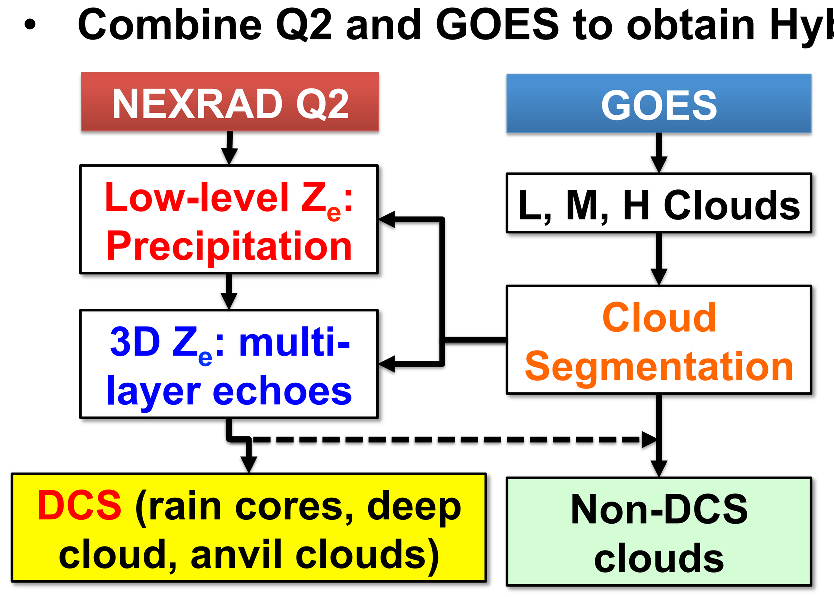
Time Period: 2009-2010 Summer - JJA (6 months)



Hybrid Classification



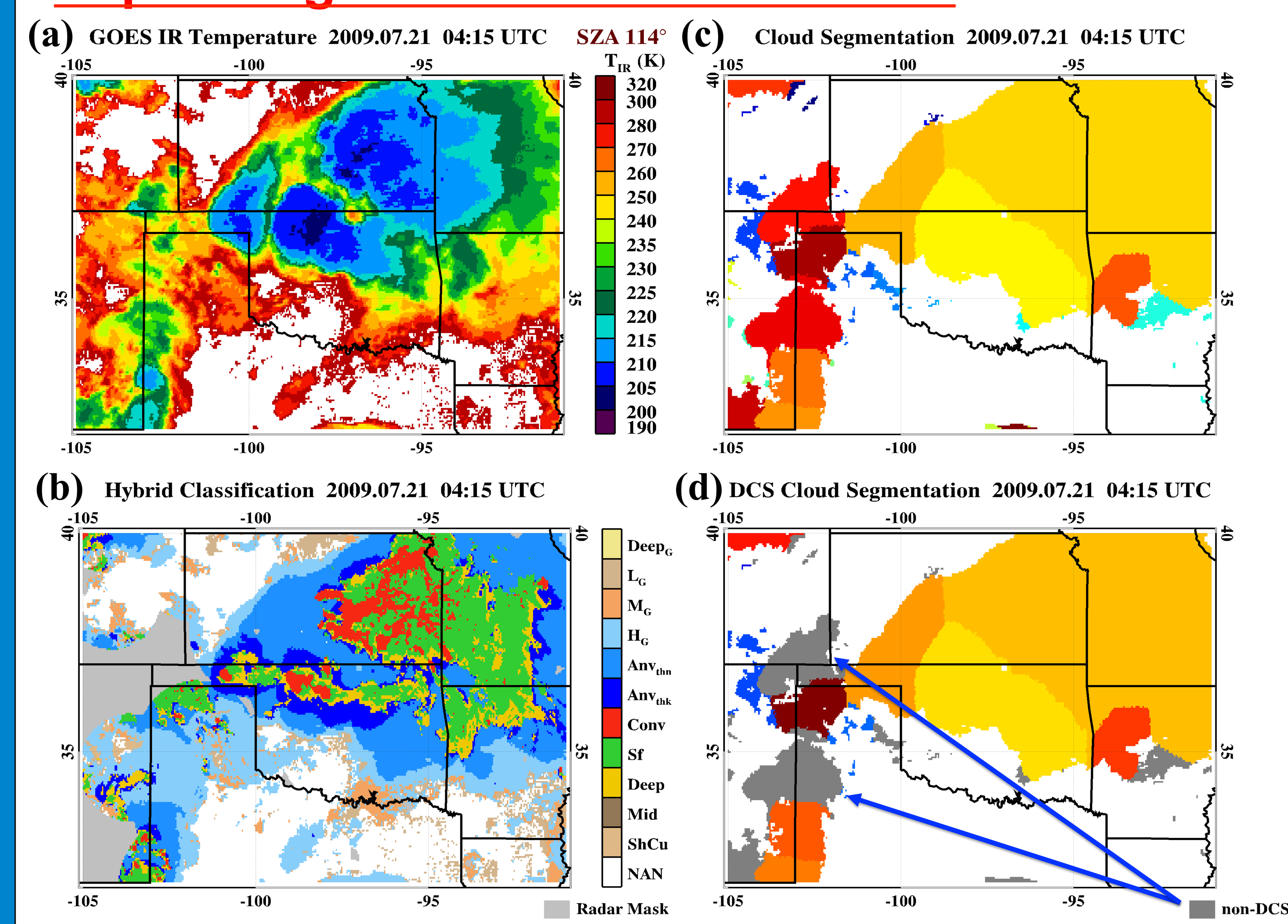
- Co-grid and time-match NEXRAD Q2 and GOES to 0.04° hybrid grid
- NEXRAD Q2: 3D reflectivity field to identify rain cores (convective / stratiform), multi-layer echoes (Deep, Low, Mid, High echoes)
- GOES cloud height retrieval: partition Low, Mid, High Clouds
- GOES T_b: high cloud patch segmentation (T_b < 260 K)
- Combine Q2 and GOES to obtain Hybrid Cloud Classification



Classify DCS clouds:

- High Cloud shield contains precipitating area > 5% total area → DCS cloud patch
- For DCS Cloud patch:
  - Q2 H-echo → thick anvil,
  - GOES H-cloud → thin anvil
- Non-DCS cloud patch clouds maintain L, M, H tags

Separating DCS Anvils from Cirrus



- High cloud patch with precipitating area < 5% is marked cirrus [gray color in panel (d)]
- Cirrus patch that is connected to a DCS patch is not considered as anvil

Computing TOA Cloud Radiative Forcing

- Ramanathan (1987): $CRF_{NET} = CRF_{SW} + CRF_{LW}$
  where

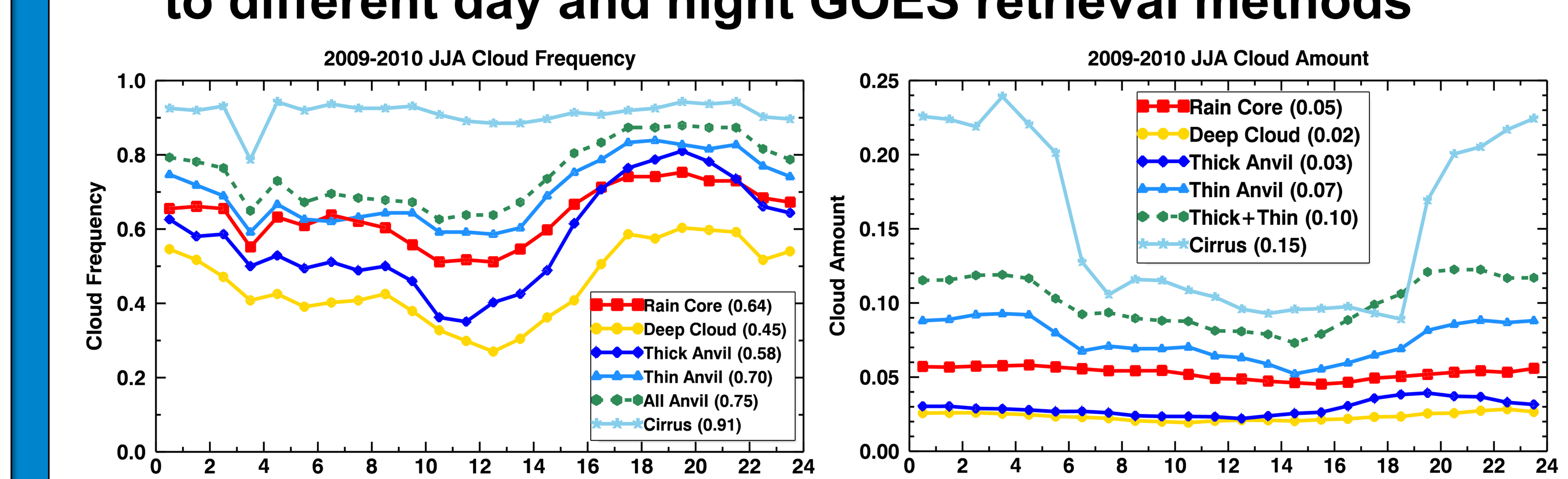
$$CRF_{SW} = S_0 \sum_i f_i \left(\alpha_{clear} - \alpha^i_{cloud}\right)$$

$$CRF_{LW} = \sum_i f_i \left(OLR_{clear} - OLR^i_{cloud}\right)$$

- Cloud fraction: $f_i = cloud\_amount_i \cdot frequency_i$
- Cloud fraction is computed for the entire domain
- Albedo (α), Outgoing Longwave Radiation (OLR) are retrieved from GOES data

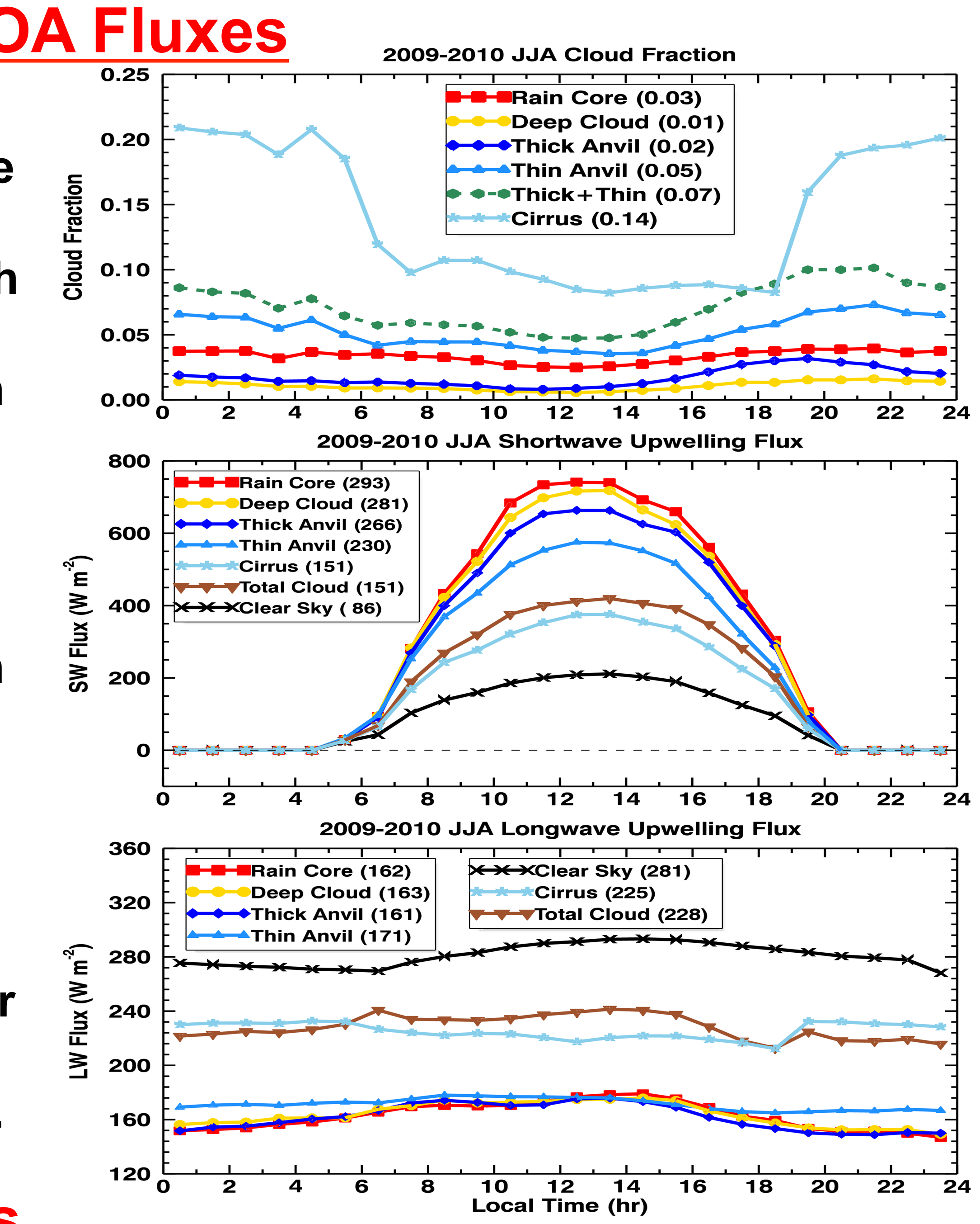
Diurnal Cycle of DCS Frequency and Amount

- DCS clouds occur frequently right after sunset
- More anvils occur during nighttime
- Significant difference in cirrus cloud amount is due to different day and night GOES retrieval methods



Cloud Fraction and TOA Fluxes

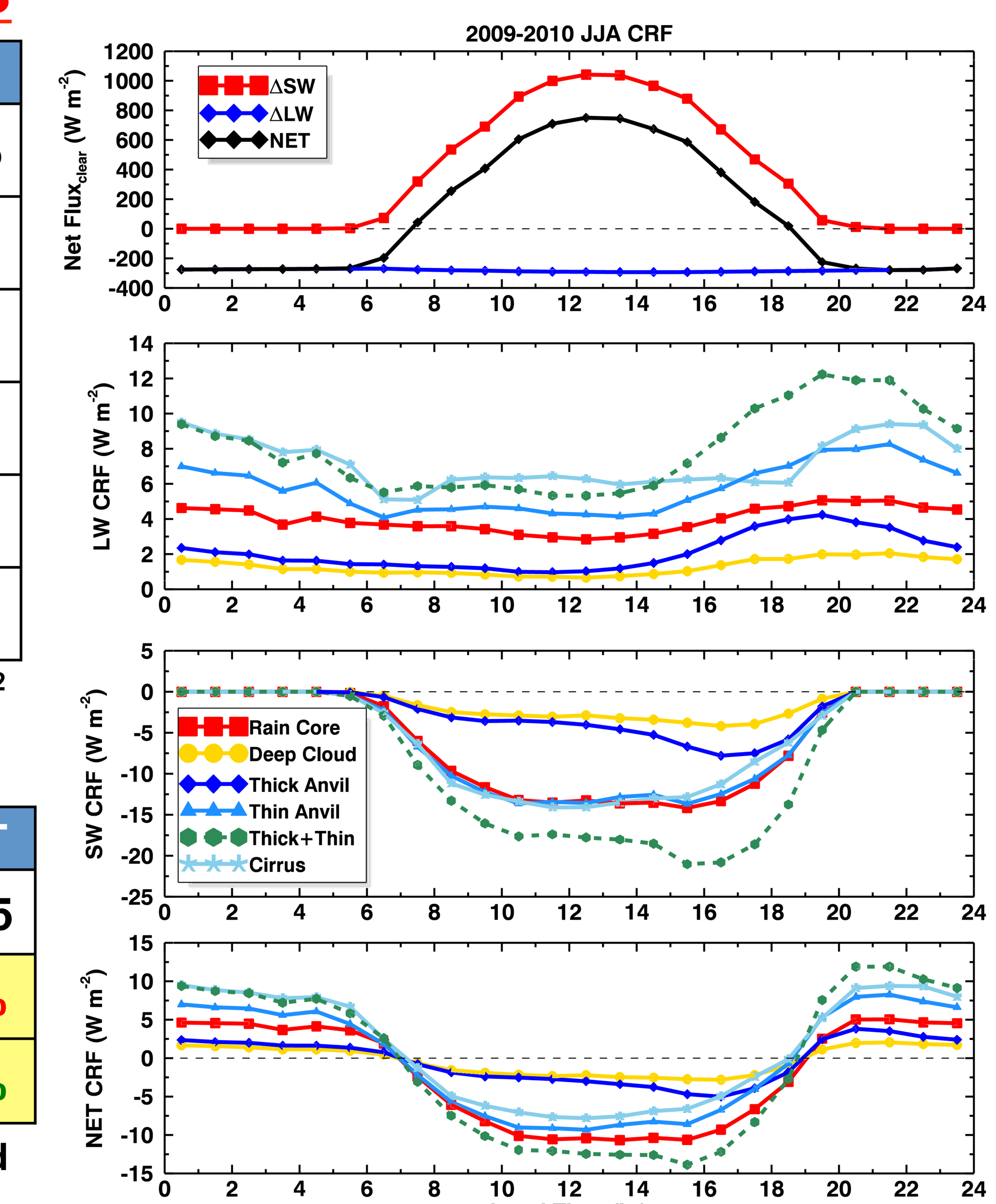
- The diurnal cycles of DCS rain core and deep cloud are weak, but anvil clouds peak at 20-hr (LT) and remain high during night.
- TOA SW upwelling flux from total cloud is almost double of clear-sky value, but it is only half of rain core average.
- SW upwelling fluxes for rain core, deep cloud and thick anvil are only distinguishable near local noon hours from satellite optical sensors.
- OLRs are nearly identical for all DCS cloud types, except thin anvils during nighttime.



CRFs weighted by CFs

	SW	LW	NET
Total	-34.0	22.5	-11.5
Rain Core	-6.1	4.0	-2.1
Deep Cloud	-1.6	1.3	-0.3
Thick Anvil	-2.5	2.1	-0.4
Thin Anvil	-6.0	5.8	-0.3
Cirrus	-6.0	7.2	1.2

Units: W m^{-2}



DCS CRF Contribution

	SW	LW	NET
Total Cloud	-34.0	22.5	-11.5
DCS Tower	22%	24%	22%
DCS Anvils	26%	35%	30%

DCS Tower = Rain Core + Deep Cloud
DCS Anvils = Thick + Thin Anvil

Summary

1) During summer months over the SGP, the average SW CRF is -34 W m^{-2} and LW CRF is 22.5 W m^{-2}, resulting in a net cooling of -11.5 W m^{-2}.
2) Of all clouds, DCS clouds contribute 48% in SW CRF, 59% in LW CRF, and 52% in NET CRF.
3) Within DCS, anvil cloud CRF (26%, 35%, 30%) contribute slightly more than DCS Tower (22%, 24%, 22%) [SW, LW, NET].