Arctic Clouds and Their Impact on Surface and TOA Radiation Budget

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Chuck Long for ARM NSA radiation data
Bob Stone for NOAA BRW radiation data
Fred Rose for Interpreting CERES CRS product
More contributors (Pat, Tom, Norman…) after my talk

Objectives

1. To compare CERES-retrieved Arctic Cloud Fractions with the DOE ARM radar-lidar and NOAA surface observed clouds over Barrow, Alaska during the period 2000-2006.
2. To compare CERES-CRS surface radiation budget with ARM and NOAA surface measurements. Through this study, we will know the uncertainties of CRS surface radiation, and then use CRS to study entire Arctic radiation budget.
3. To estimate TOA radiation budget from CERES-CRS dataset, and then combined with ARM surface radiation to infer the Atmospheric SW absorption (as we did in Dong et al. 2008).

ARM NSA and NOAA BRW data

Cloud fraction:

➔Cloud fraction: Derived from ARM radar-lidar pair measurement during 1999-2004.

➔Cloud fraction: derived from ARM ceilometer measurement during 1998-2008.

➔Cloud fraction: derived from NOAA Barrow surface Obs (both ceilometer+human) during 1998-2008.

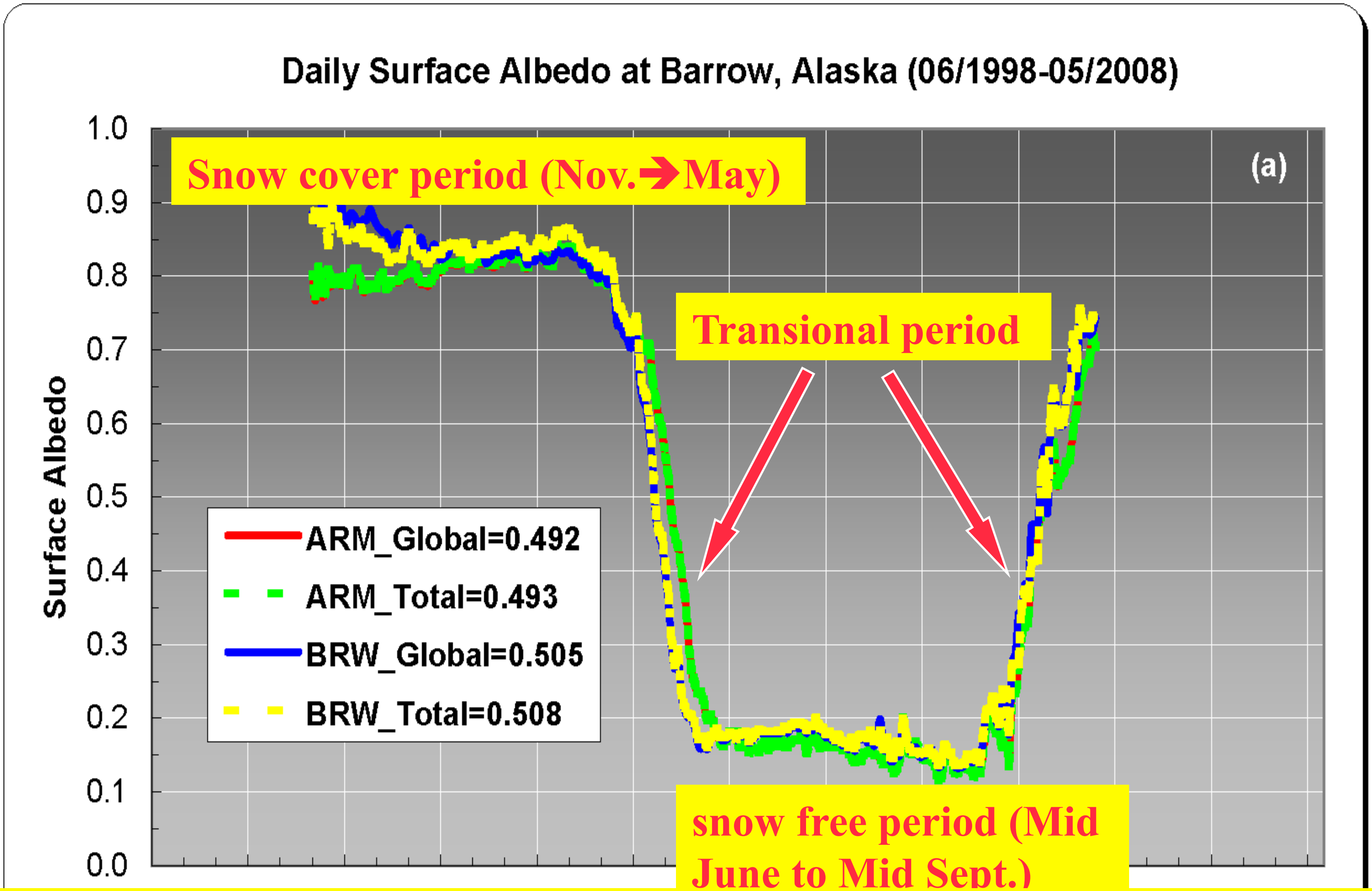
Surface Radiation data (1998-2008)

➔ARM: All-sky measured by PSPs and PIRs
Clear-sky inferred by Chuck Long

➔NOAA: All-sky measured by PSPs and PIRs
Clear-sky inferred by Chuch Long

CERES CRS product (1ºX1º)

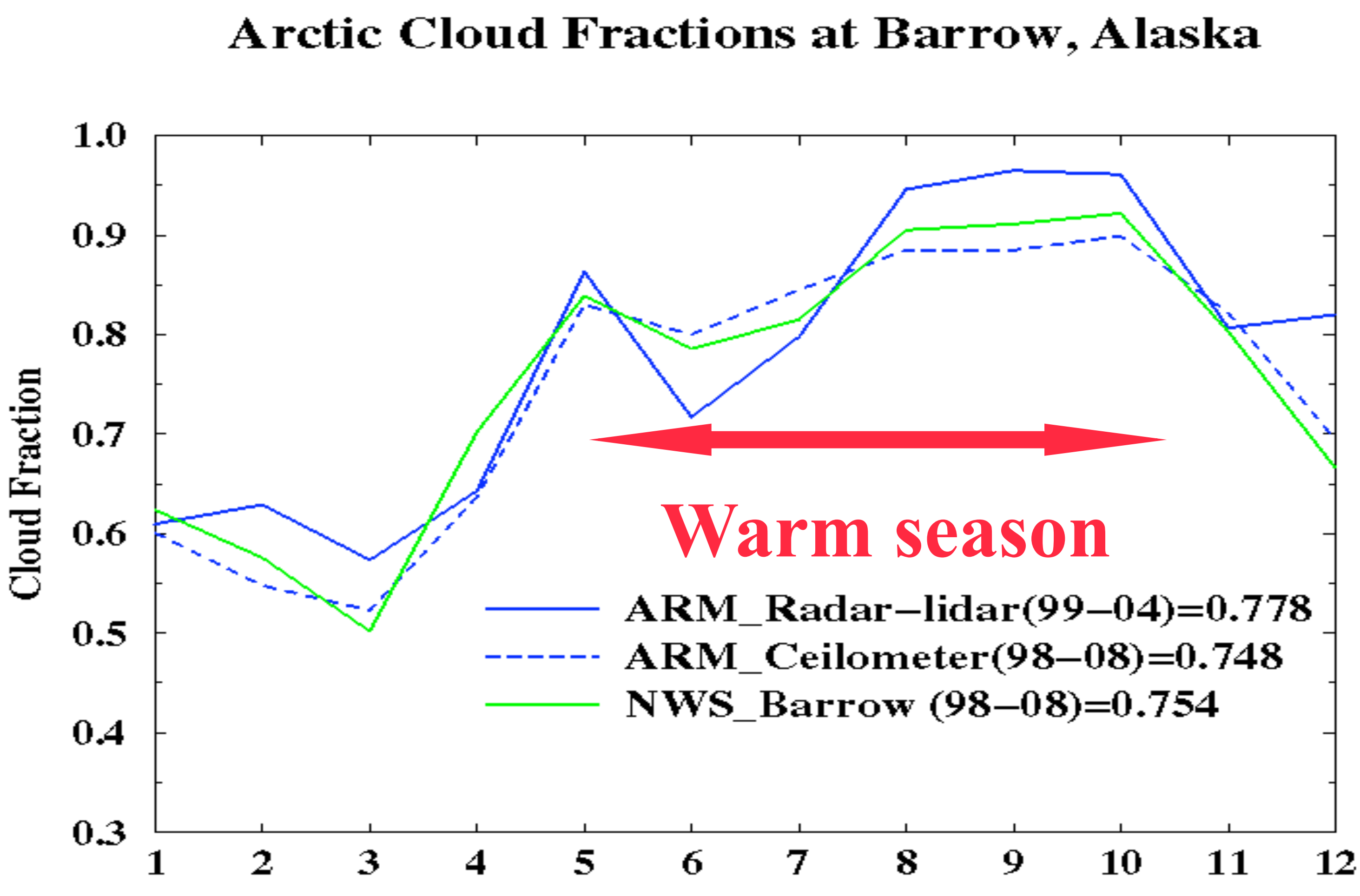
- ➔Terra FM1 and FM2 edition 2B, 3/2000 – 7/2006, they all are cross-track scanning strategy
- ➔Aqua FM3 and FM4 edition 2B, 7/2002 – 4/2006, they all are cross-track scanning strategy
- ➔Variables listed as "all-sky" and "clear-sky" are CERES-MODIS tuned fluxes with add CRS adjustments. These are Langley modified Fu-Liou scheme.
- ➔Variables listed as "FM1/3" and "FM2/4" in comparison plots are the same. REV1 changes were added for TOA variables.



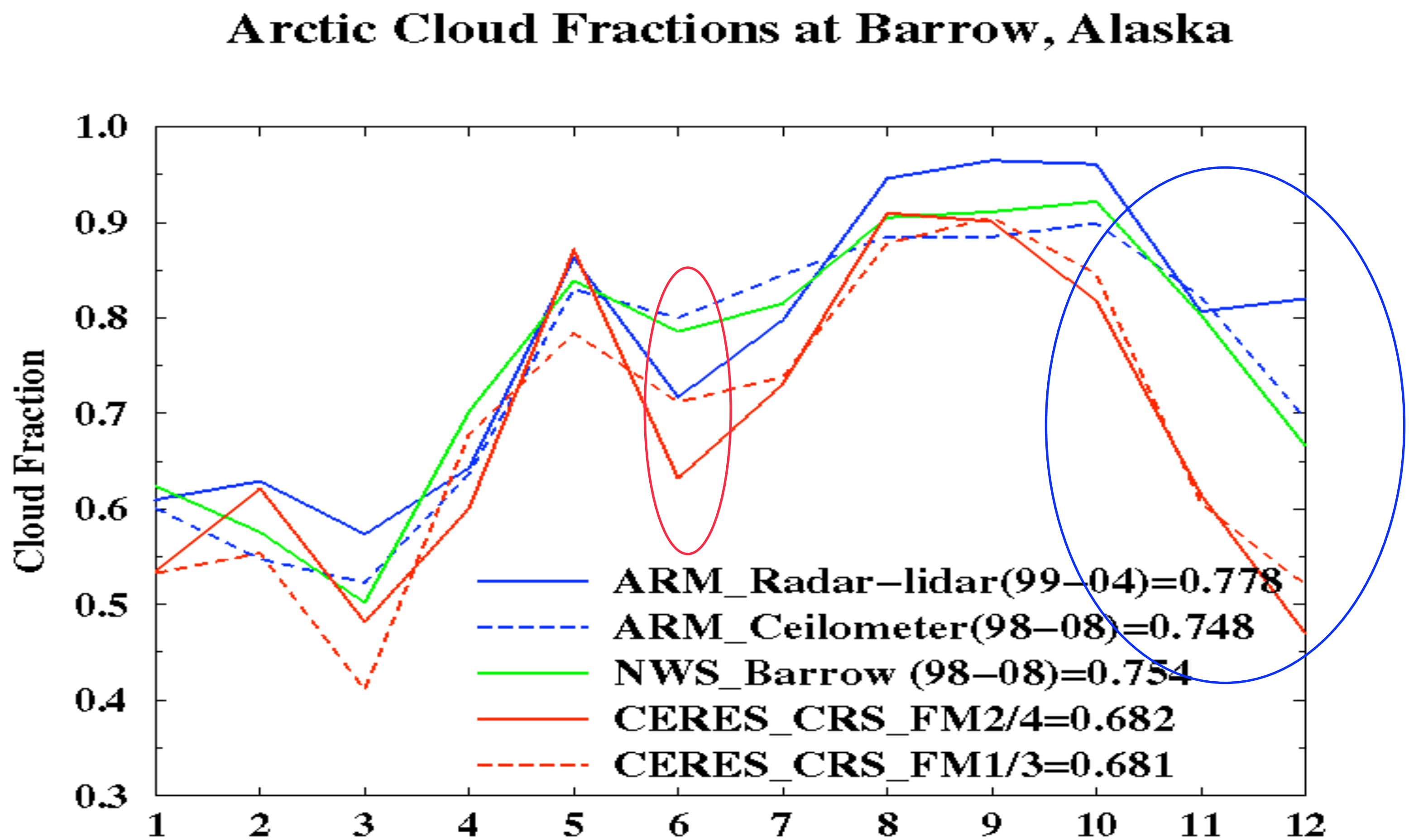
Different surface albedos may result in different cloud and radiation property retrievals from satellites

Objective 1

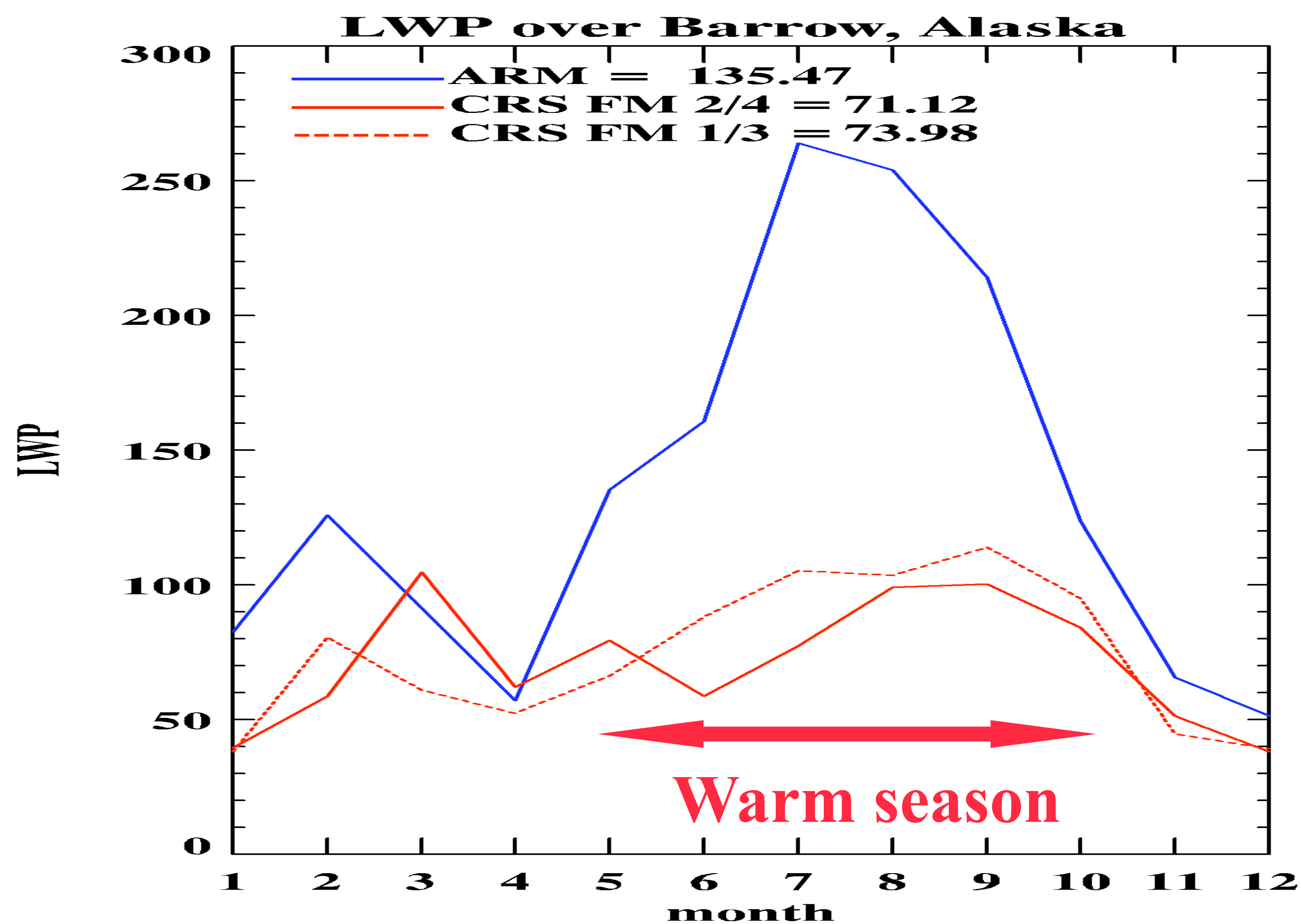
To compare CERES-retrieved Arctic Cloud Fractions with the DOE ARM radar-lidar and NOAA surface observed clouds over Barrow, Alaska during the period 2000-2006.



1. CFs increase significantly from March to May, remain high (0.8-0.9), and drop off during winter months.
2. There are more clouds during warm season (T=267➔277K) than cold season (T=247➔257K) due to more southerly flow (bring more moisture air mass)



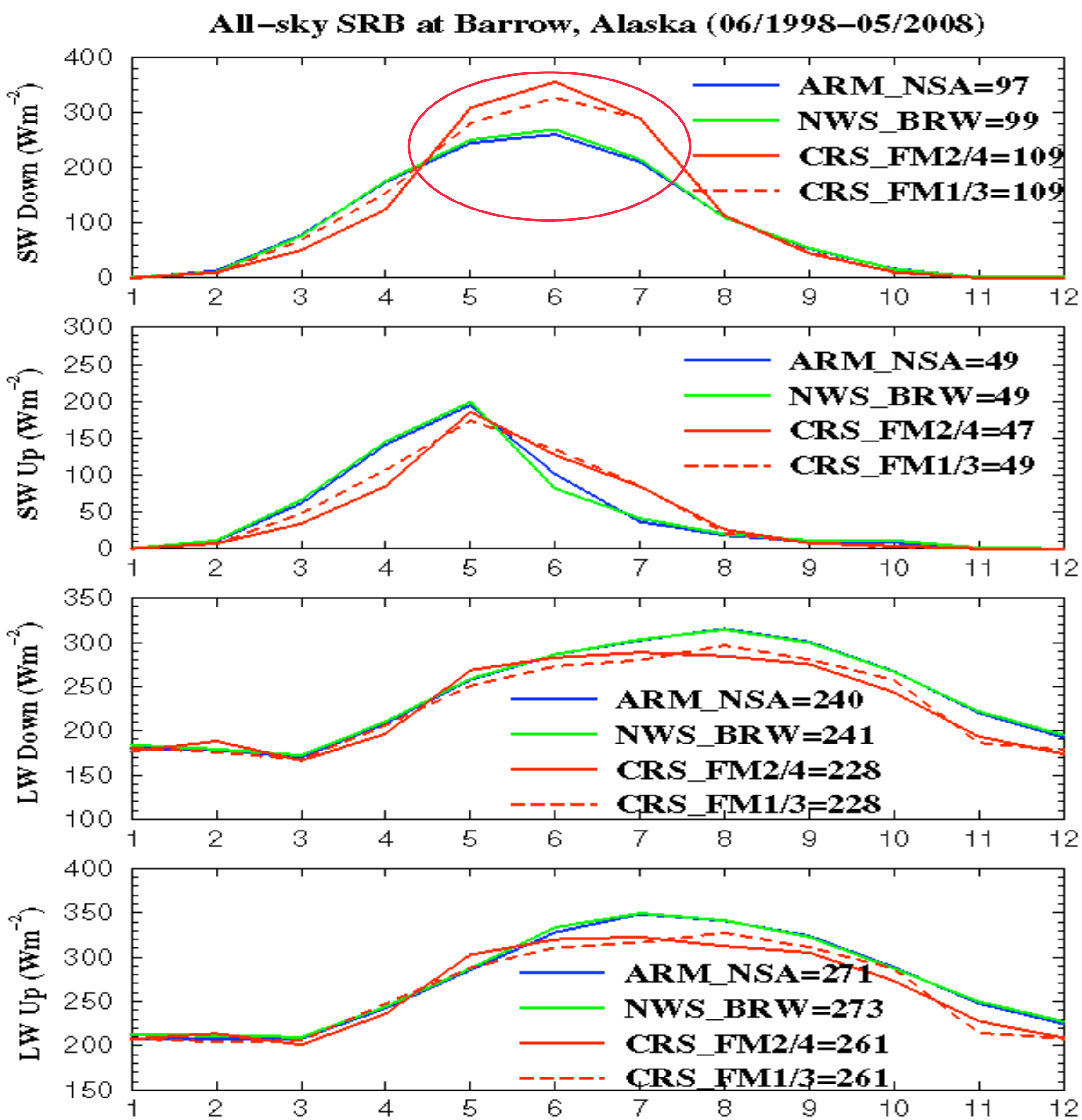
1. Both surface and Satellite derived CFs have the same trends.
2. MODIS derived CFs agree well with ARM and NOAA CFs during Feb-Sept., but lower during Oct-Jan (due to different cloud masks?)
3. In June, the ceilometer derived CFs are higher than radar and MODIS derived CFs because some of fogs below 105 m (radar low limit) and fogs' temp is the same as ground (for MODIS)



ARM LWPs are much higher during warm season (May→Oct) due to more southerly flow (more warm , moist air mass).
They are much higher than MODIS retrieved LWPs.

Objective 2

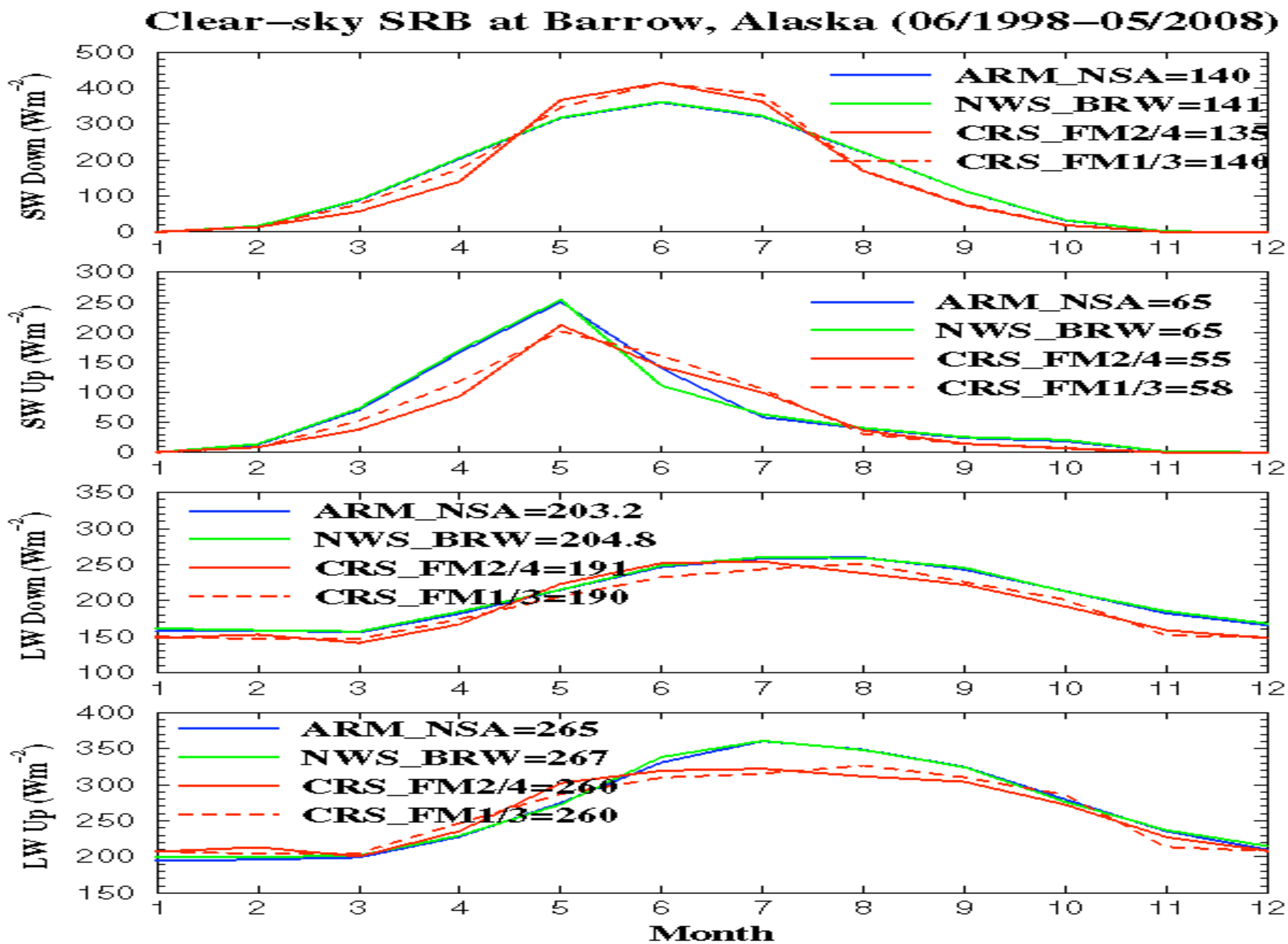
To compare CERES-CRS surface radiation budget with ARM and NOAA surface measurements. Through this study, we will know the uncertainties of CRS surface radiation, and then use CRS to study entire Arctic radiation budget.



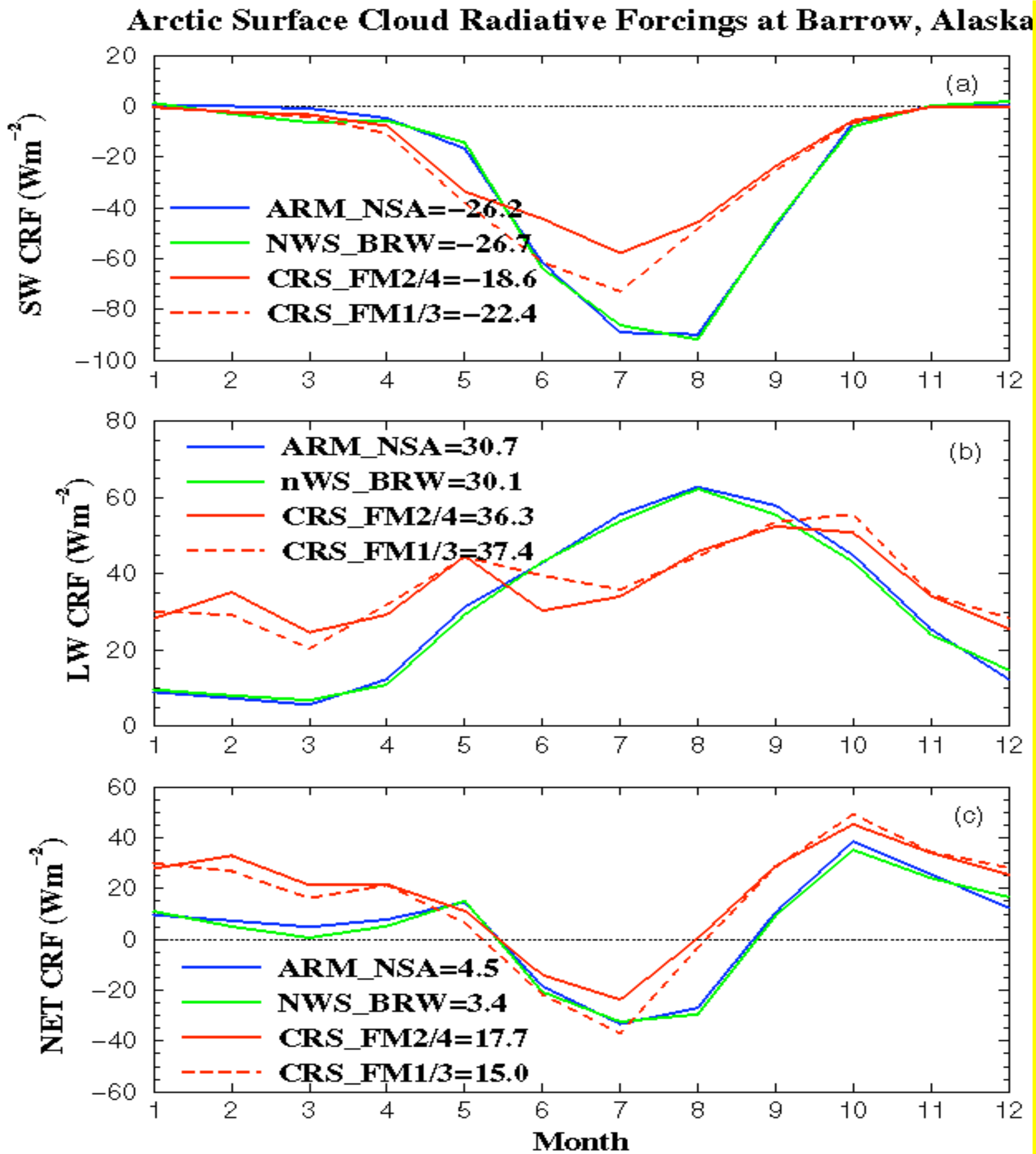
SW flux:
1. During March-April, CRS are lower than ARM and NOAA data (possible due to surface albedo)
2) During May-July, CRS are much higher than ARM and NOAA data (possible due to optically thin clouds retrieved by MODIS, but cannot explain Aug-Sept).

LW-down flux:
CRS are lower than ARM and NOAA data due to optically thin and low CFs.

Overall, CRS calculated SW and LW fluxes agree with ARM and NOAA long-term observations in ~10 Wm^2.



The comparisons for clear-sky fluxes are very similar to their all-sky counterparts.



➔More negative SW and positive LW CRFs during summer (snow free).

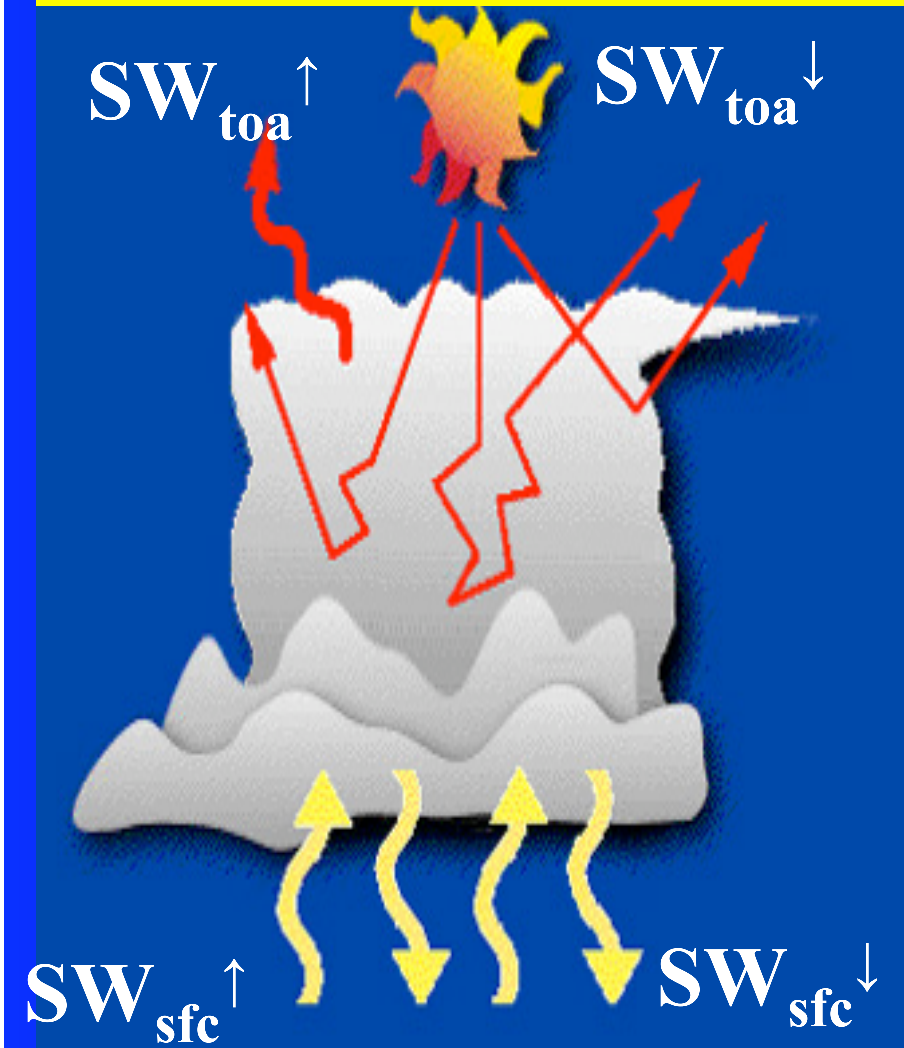
➔CRS calculated SW and LW CRFs agree within ~8 Wm^{-2} on annual average, but up to ~40 Wm^{-2} for individual months.

On annual average, the negative SW CRF and positive LW CRF tend to cancel, resulting in annual average NET CRF of 4 Wm^{-2}.

Objective 3

To estimate TOA radiation budget from CERES-CRS dataset, and then combined with ARM surface radiation to infer the Atmospheric SW absorption (as we did in Dong et al. 2008).

Using both surface and TOA radiation data to study:



- How much SW **is reflected** back to space?

  $R_{toa}=SW_{toa}\uparrow/SW_{toa}\downarrow$

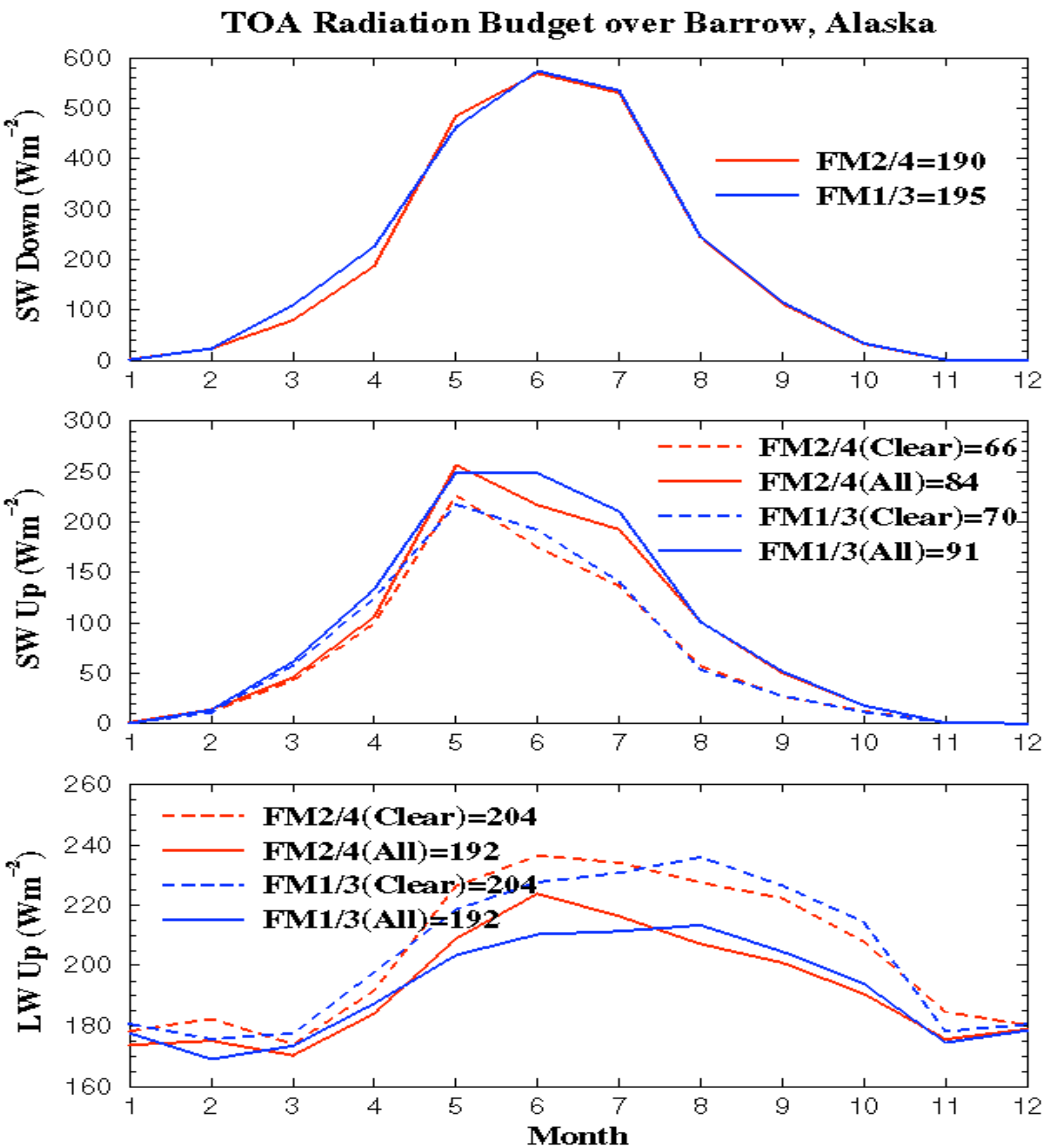
- How much SW **is absorbed** at the Earth surface?

  $A_{sfc}=(SW_{sfc}\downarrow- SW_{sfc}\uparrow)/SW_{toa}\downarrow$

- How much SW **is absorbed** by atmospheric column

  $A_{col}=1 – R_{toa} - A_{sfc}$

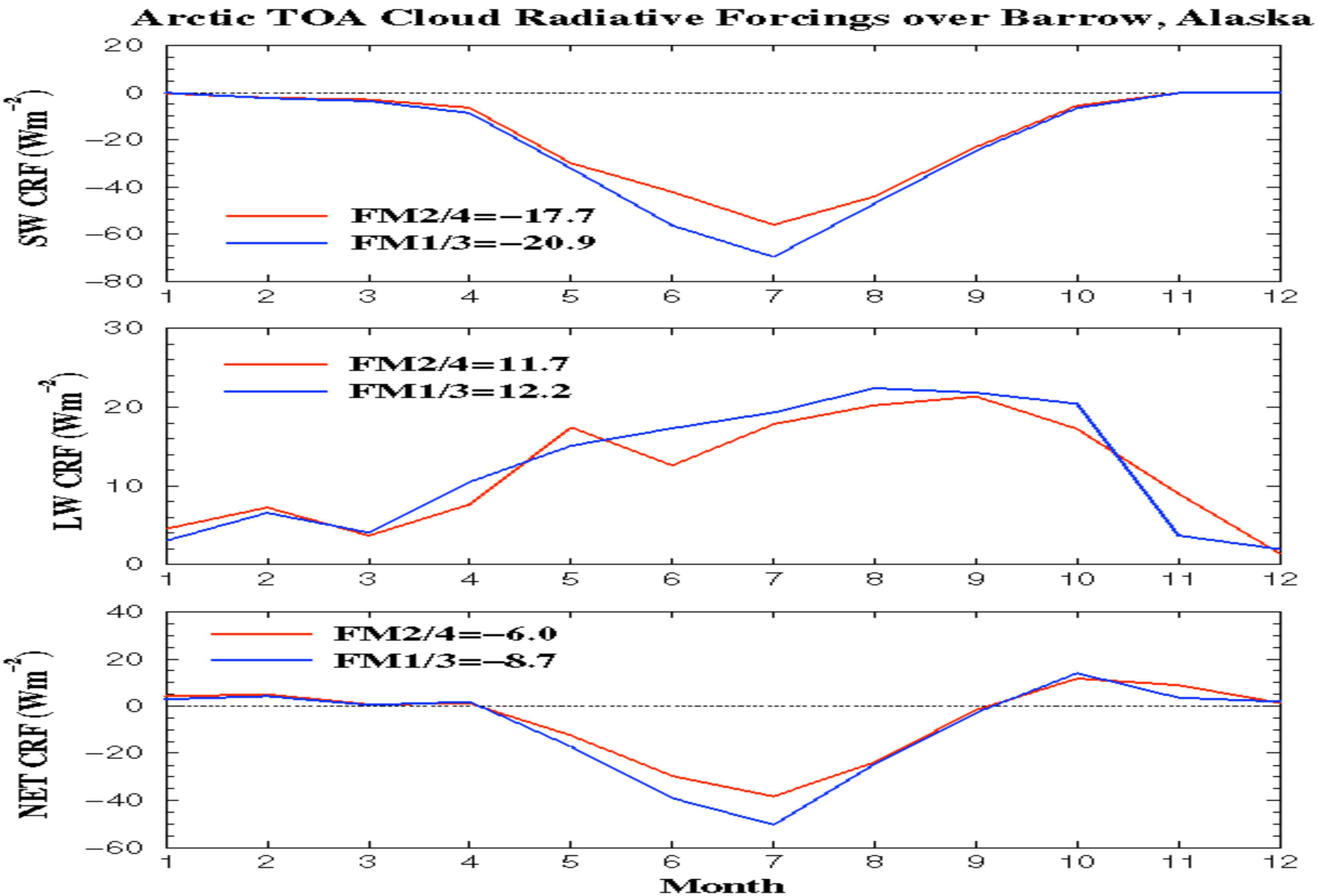
In this study, we calculate the monthly means of all-sky values, so the uncertainties are large.



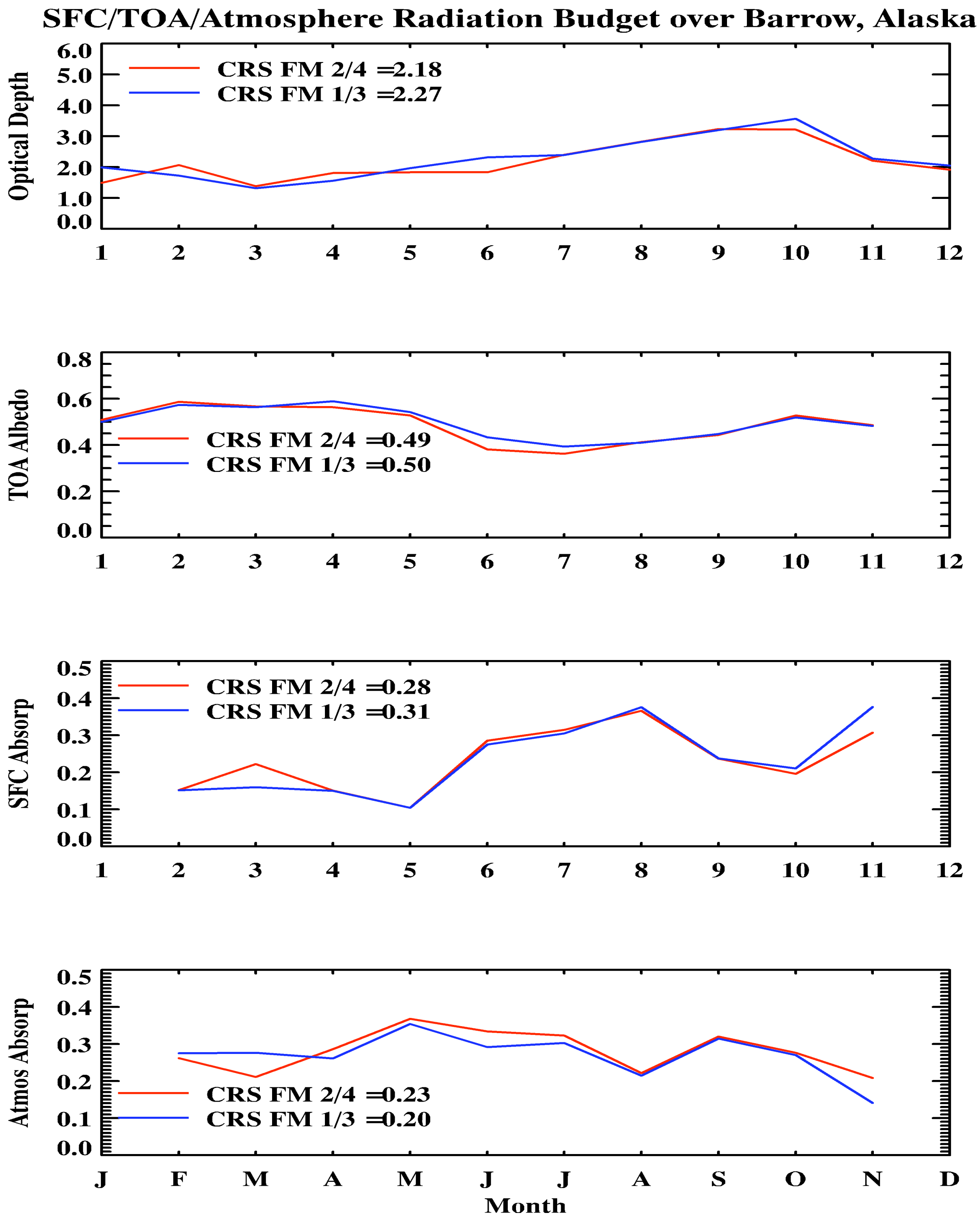
➔There are 5 Wm^{-2} difference in SW down at TOA between FM2/4 and FM1/3, primarily during March-April.

➔All-sky SW reflects about 20 Wm^{-2} more than clear-sky, mainly in summer.

➔Clear-sky OLR emits ~12 Wm^{-2} than all-sky, mainly from May-Oct (when surface was heated).



TOA CRFs are very similar to their surface counterparts, such as negative SW and positive LW CRFs, but with negative net CRFs annually.



➔ NO strong seasonal variation for optical depth.

➔ Higher TOA albedo during Spring than summer is due to snow contribution (same tau during spring and summer)

➔MORE Surface SW absorption during summer months (snow free)

➔NO strong seasonal variation for atmospheric SW absorption. .

Summary

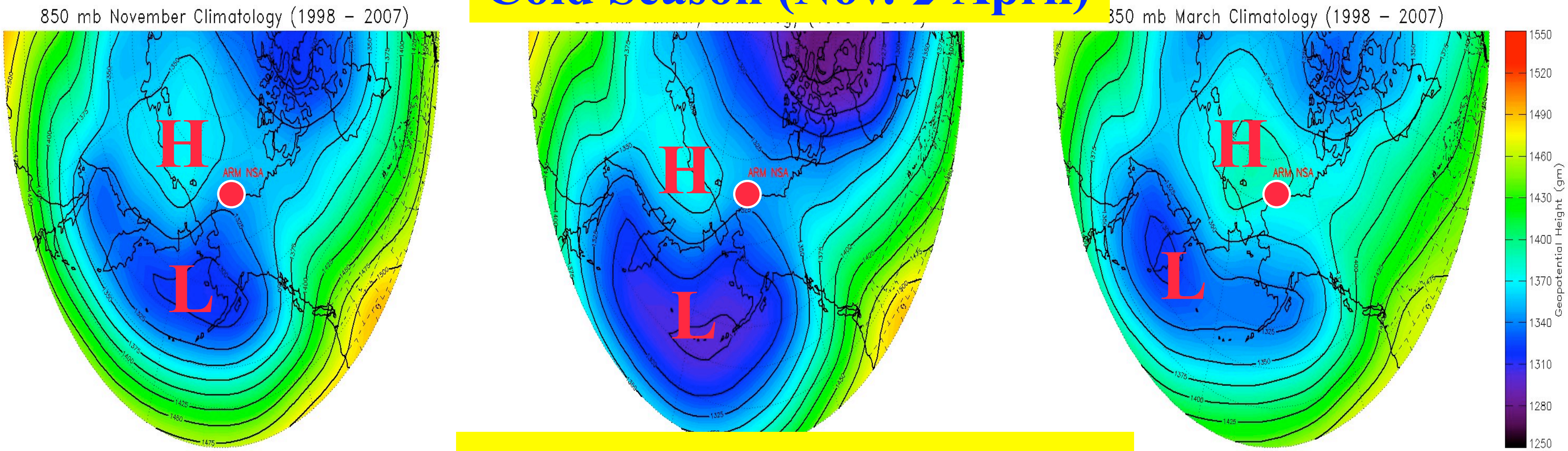
1. Both surface and Satellite derived CFs have the same seasonal variation, a good agreement during Feb-Sept., but have discrepancy during winter months (due to cloud masks)

2. On annual average, CRS calculated surface SW and LW fluxes agree ~10 W m^{-2} with ARM and NOAA observed fluxes, but there are large differences for individual months (due to surface albedo and cloud retrievals).

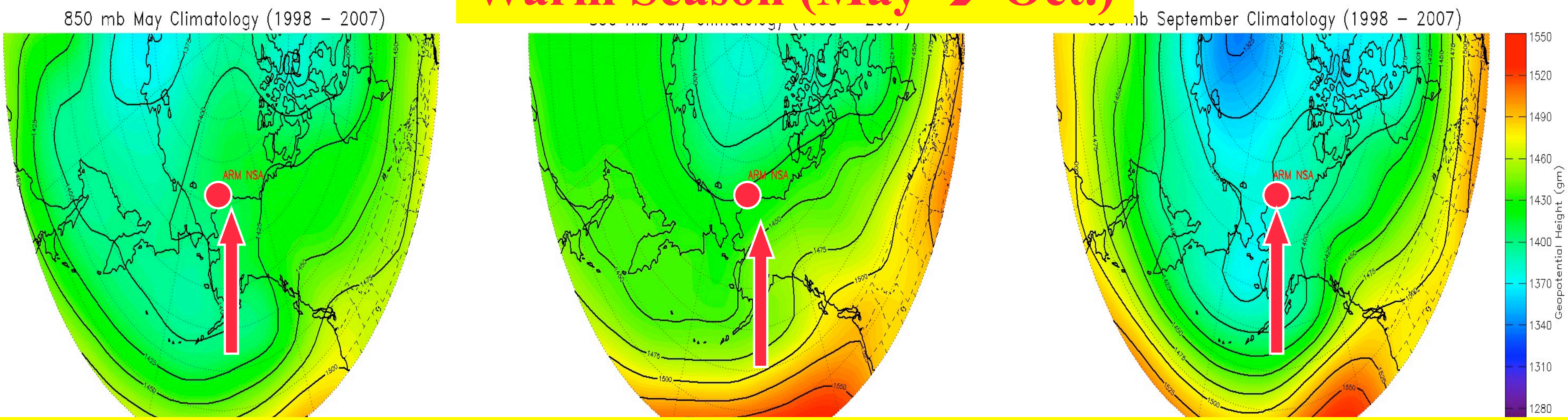
3. Low TOA albedo and high surface SW absorption during summer➔No seasonal variation for atmospheric SW absorption.

850 mb Geopential Height (1998-2007) over Alaska

Cold Season (Nov.➔April)



Warm Season (May ➔ Oct.)



The patterns of 850 mb GH from May through October favor southerly flow which transports warm, moist air masses to Barrow➔enhance cloudiness.