Investigating the CERES Ed4 and Ed2 cloud properties using DOE ARM measurements at Barrow and Atqasuk sites

Baike Xi, Xiquan Dong and Shaoyue Qiu, UND
Pat Minnis and Sunny Sun-Mack,NASA LaRc

Publications

Submitted

- **Stanfield, R., X. Dong, B. Xi, A. Gel Genio, P. Minnis, and J. Jiang: Assessment of NASA GISS CMIP5 and post-CMIP5 Simulated Clouds and TOA Radiation Budgets Using Satellite Observations: Part I: Cloud fraction and properties. Submitted to J. Clim.**
- **Dong, X., B. Xi, A. Kennedy, P. Minnis and R. Wood, 2013: A 19-month record of Marine Aerosol-Cloud-Radiation Properties derived from DOE ARM AMF deployment at the Azores: Part I: Cloud Fraction and Single-layered MBL cloud Properties. Submitted to J. Clim.**

Will be submitted before the end of this year:

- **Giannecchini, K., X. Dong, B. Xi, A. Kennedy, P. Minnis, and S. Kato, 2013: Comparison of CERES-MODIS Edition-2 cloud properties with CloudSat/CALIPSO and ground-based measurements at the DOE ARM North Slope of Alaska site. Will be re-submitted to JGR.**
- **Stanfield, R., X. Dong, B. Xi, A. Gel Genio, P. Minnis, D. Doelling, and N. Loeb: Assessment of NASA GISS CMIP5 and post-CMIP5 Simulated Clouds and TOA Radiation Budgets Using Satellite Observations: Part II: TOA Radiation Budgets and Cloud Radiative Forcings. In preparation for J Clim.**
- **Xi, B., X. Dong, P. Minnis, S. Sun-Mack, 2013: Validation of CERES-MODIS Edition 4 Marine Boundary Layer Cloud Properties using DOE ARM AMF Measurements at the AZORES. In preparation for JGR.**

Motivation/Scientific Questions

1) Does ceilometer derived CF represent real CF over Arctic ?

- **Cloud radar, MMCR at Barrow site only (quite often without data);**
- **Ceilometers (with 94% working time) at both Barrow and Atqasuk;**

2) Is the CF difference between two surface sites reasonable?

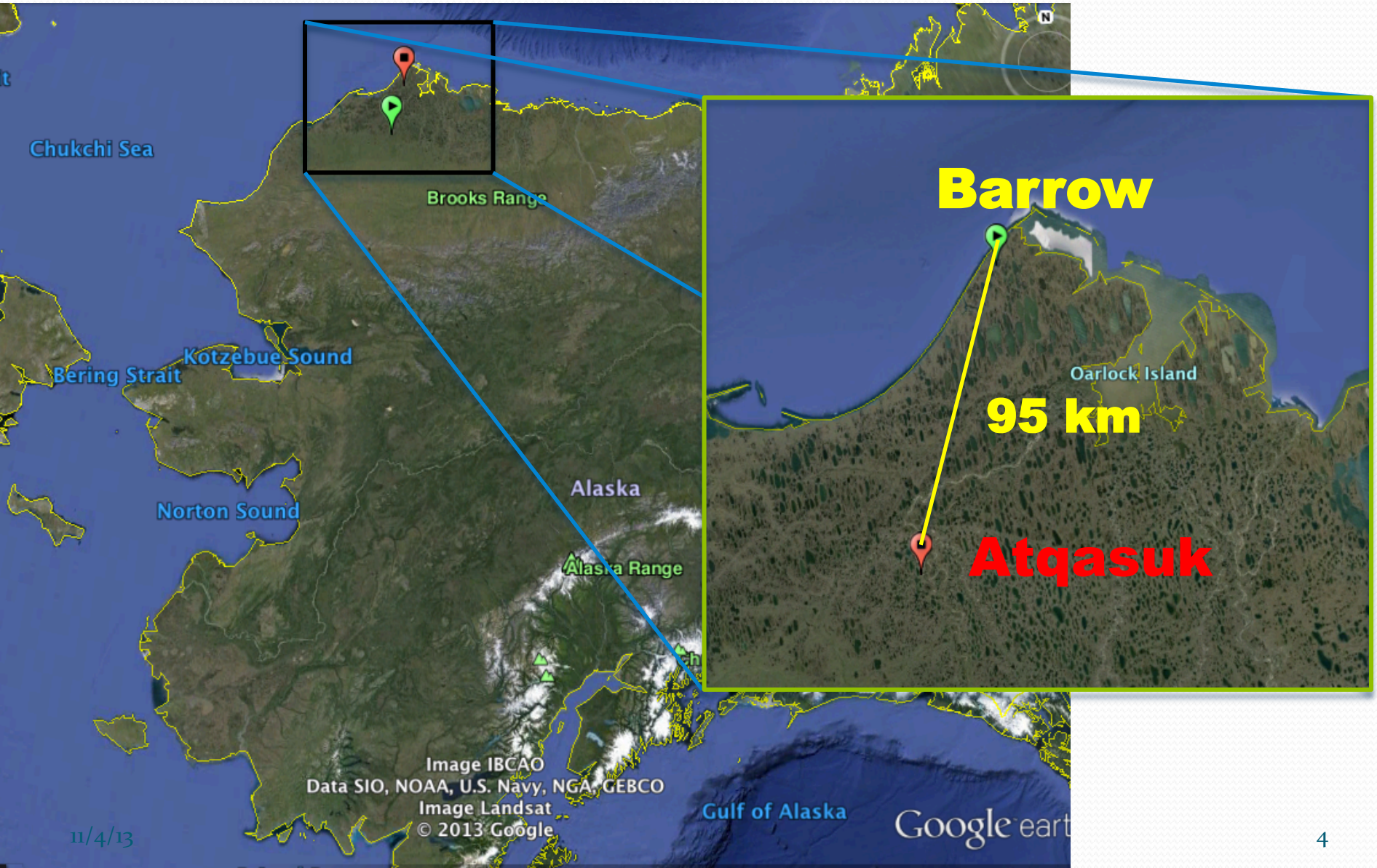
Annual CFs over the 5 grid boxes (North-South) near two sites

3) Any improvements of the CERES Ed4 derived CF over Arctic regions compared to Ed2?

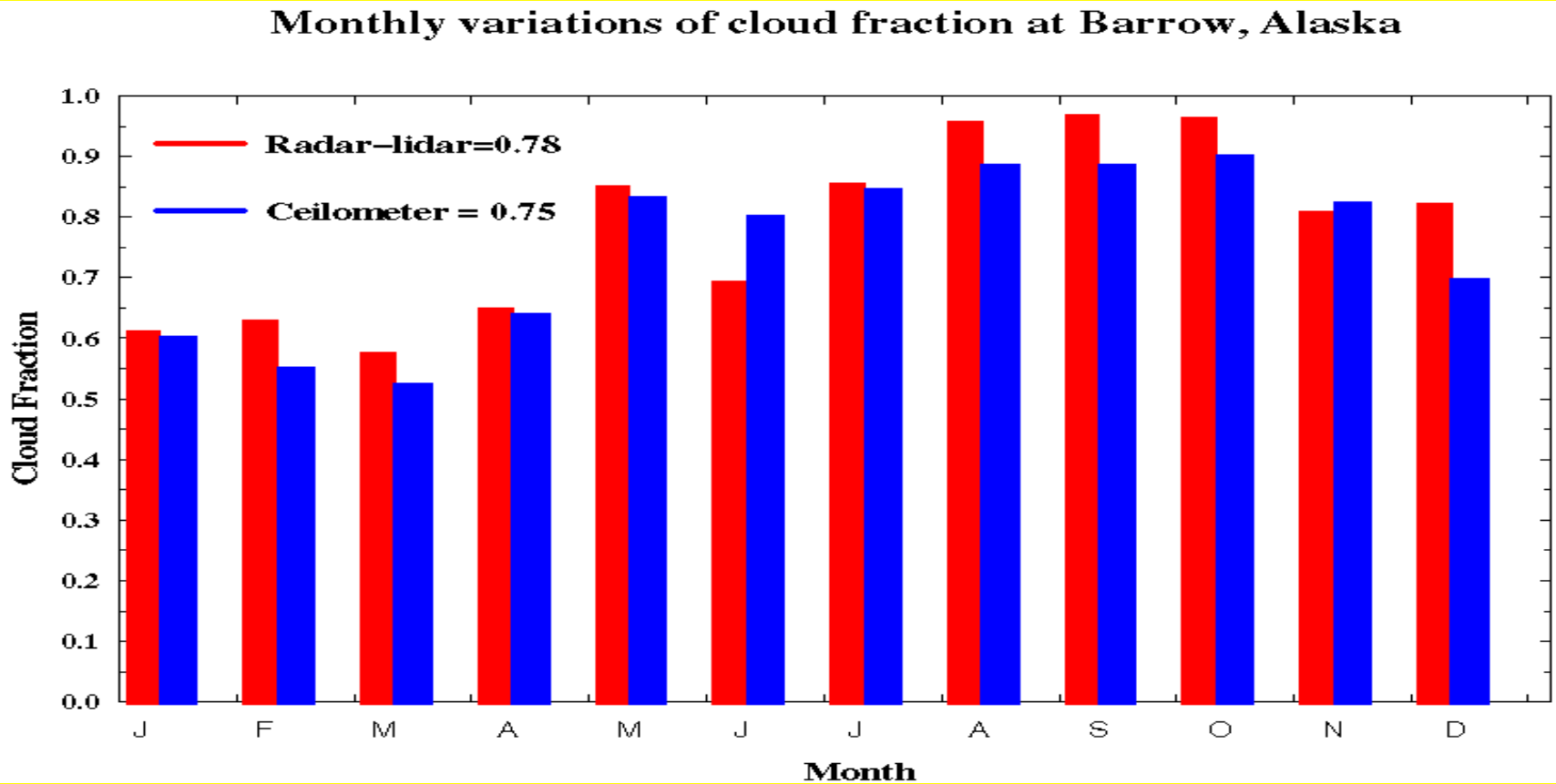
- **Cloud fraction over snow/ice surface**
- **Cloud fraction during polar night**
- **Cloud fraction for multilayered clouds**

4) Do the Ed4 cloud height retrievals agree with ARM NSA radar-lidar measurements?

1) Two sites in Northern Slope of Alaska



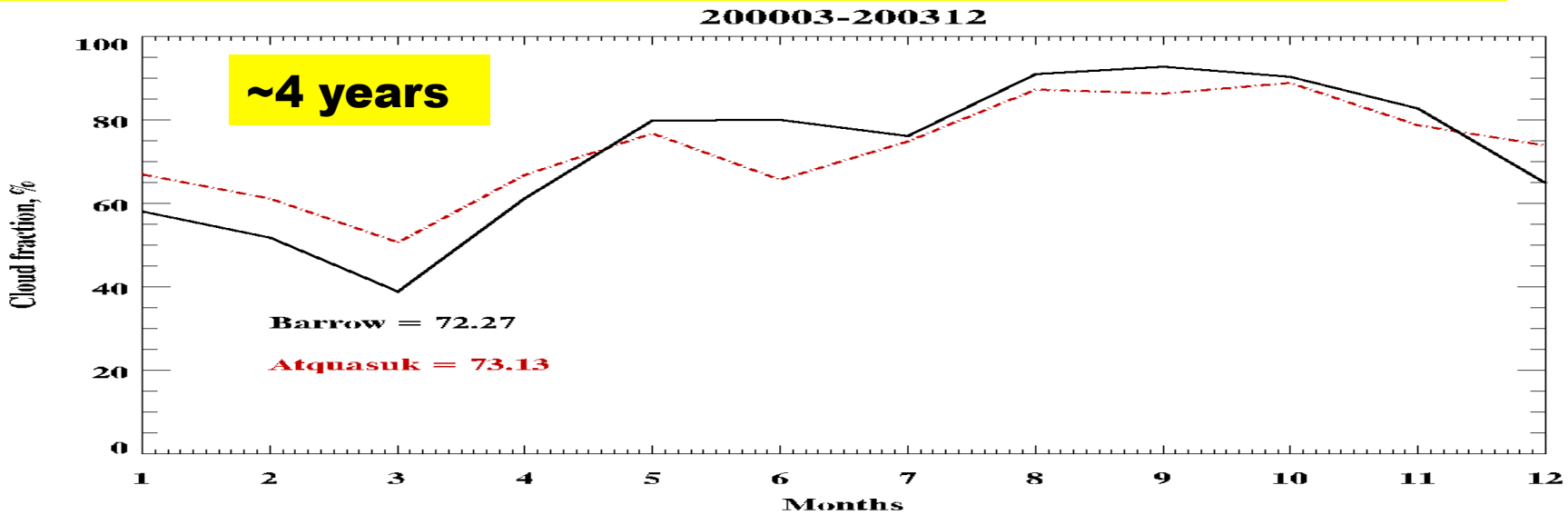
Does ceilometer derived CF represent real CF over Arctic ?

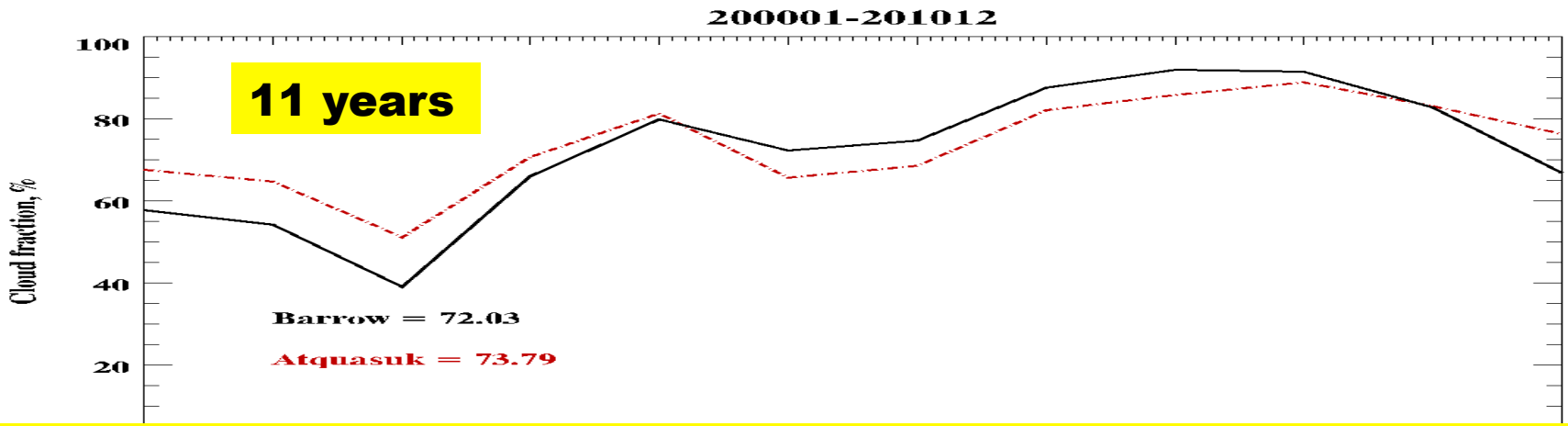


1) CF difference is only 3% between radar and ceilometer at ARM NSA site (1998-2008). (Dong et al. 2010, JGR)
2) Radar can detect all clouds from surface to 16 km, but may miss some optically thin clouds (particular cirrus over stratus). While ceilometer can detect cloud base up to 7.6 km, but may miss some cloud bases higher than 7.6km, particular during summer months.

(3) Conclusion: ceilometer derived CFs have the same seasonal variation as radar ones, and nearly the same monthly means because no many clouds above 7.6 km Over Arctic regions.

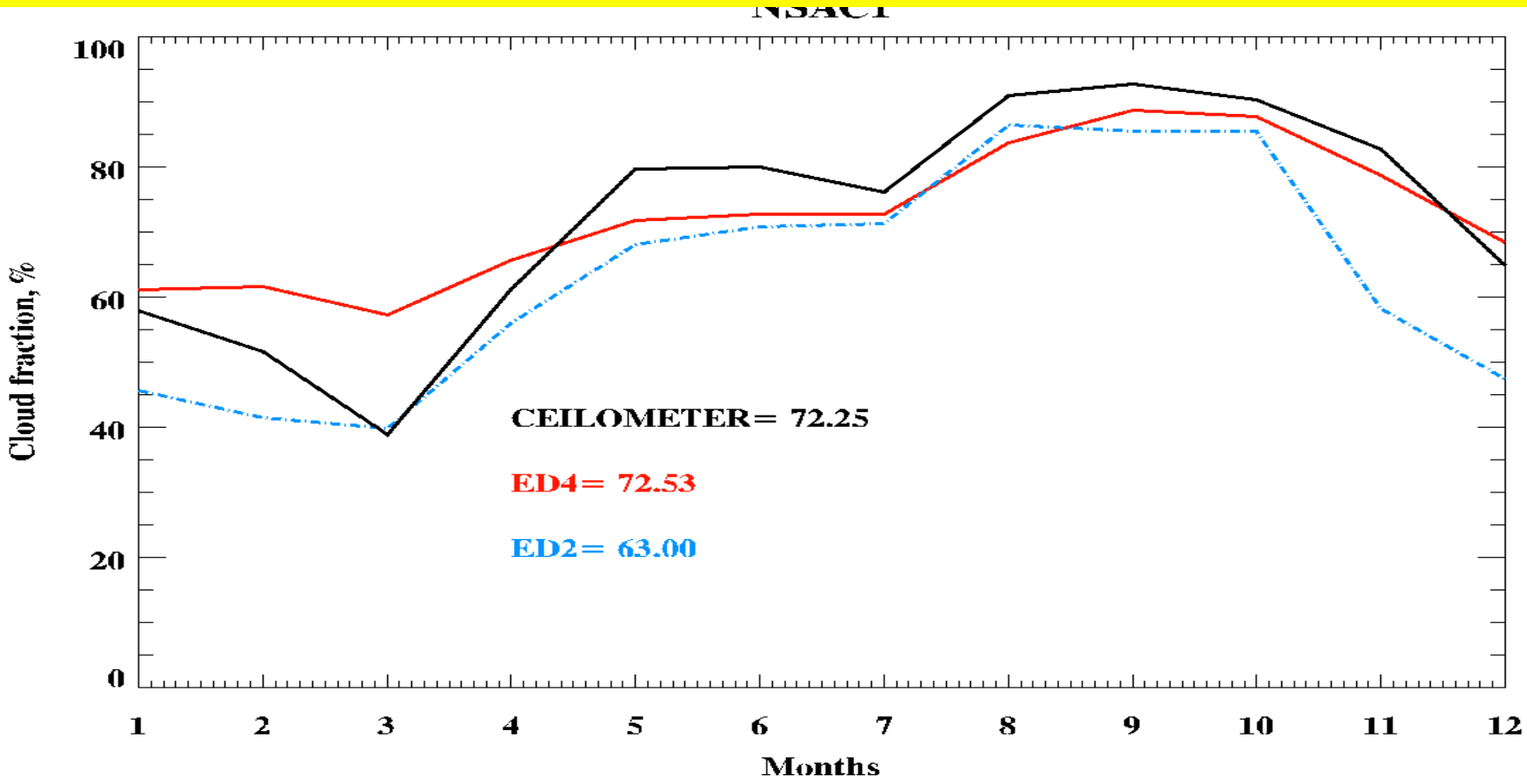
Ceilometer-derived CFs at Barrow and Atqasuk sites





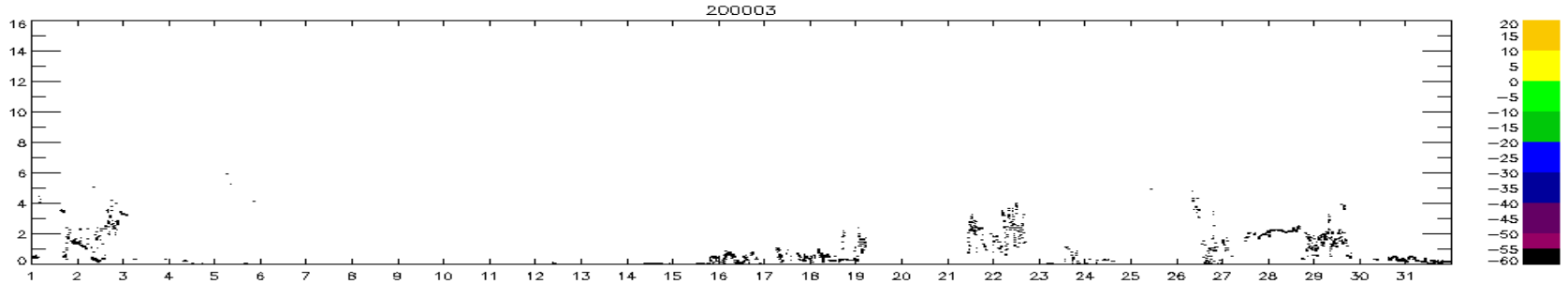
(1) The annual averages CFs during 4-yr and 11-yr periods are nearly the same
(2) The CF differences between two sites during 4-yr and 11-yr period are also similar.
(3) The annual trends from two time periods are similar, therefore, we can use ceilometer-derived CFs to validation the CERES-MODIS derived CFs.

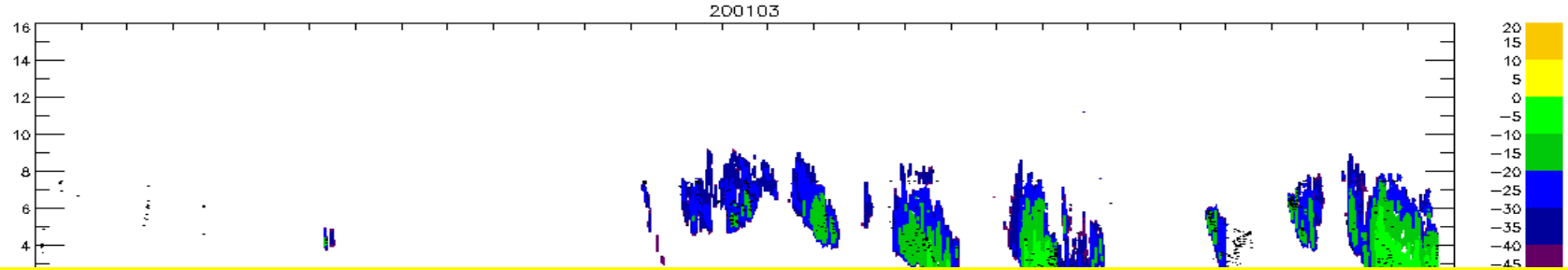
Comparing ceilometer-derived CFs with CERES-MODIS Ed4 and Ed2 CFs at Barrow site (2000-2003)



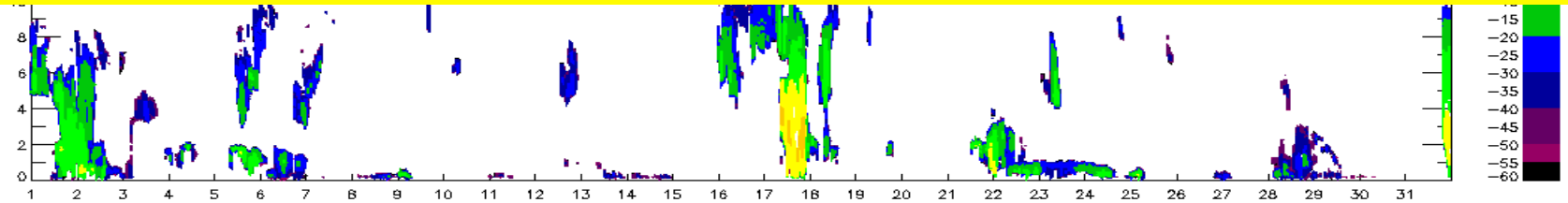
→Annually averaged ARM and Ed4 CFs are the same (72.5%), ~10% higher than Ed2 CFs, a significant improvement in Ed4 CF retrievals, particular during Polar night and/or snow/ice cover period.

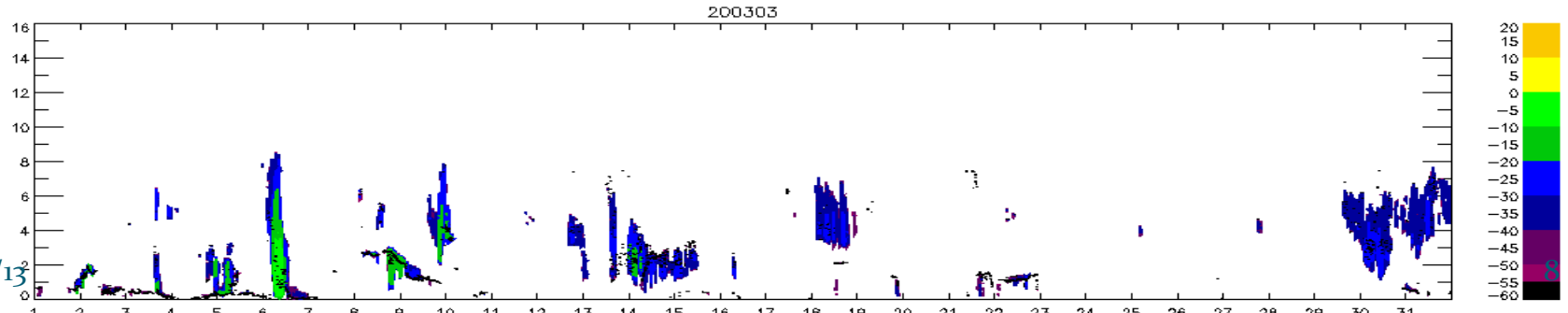
→Large difference occurred in some months, such as March, need more detailed study.



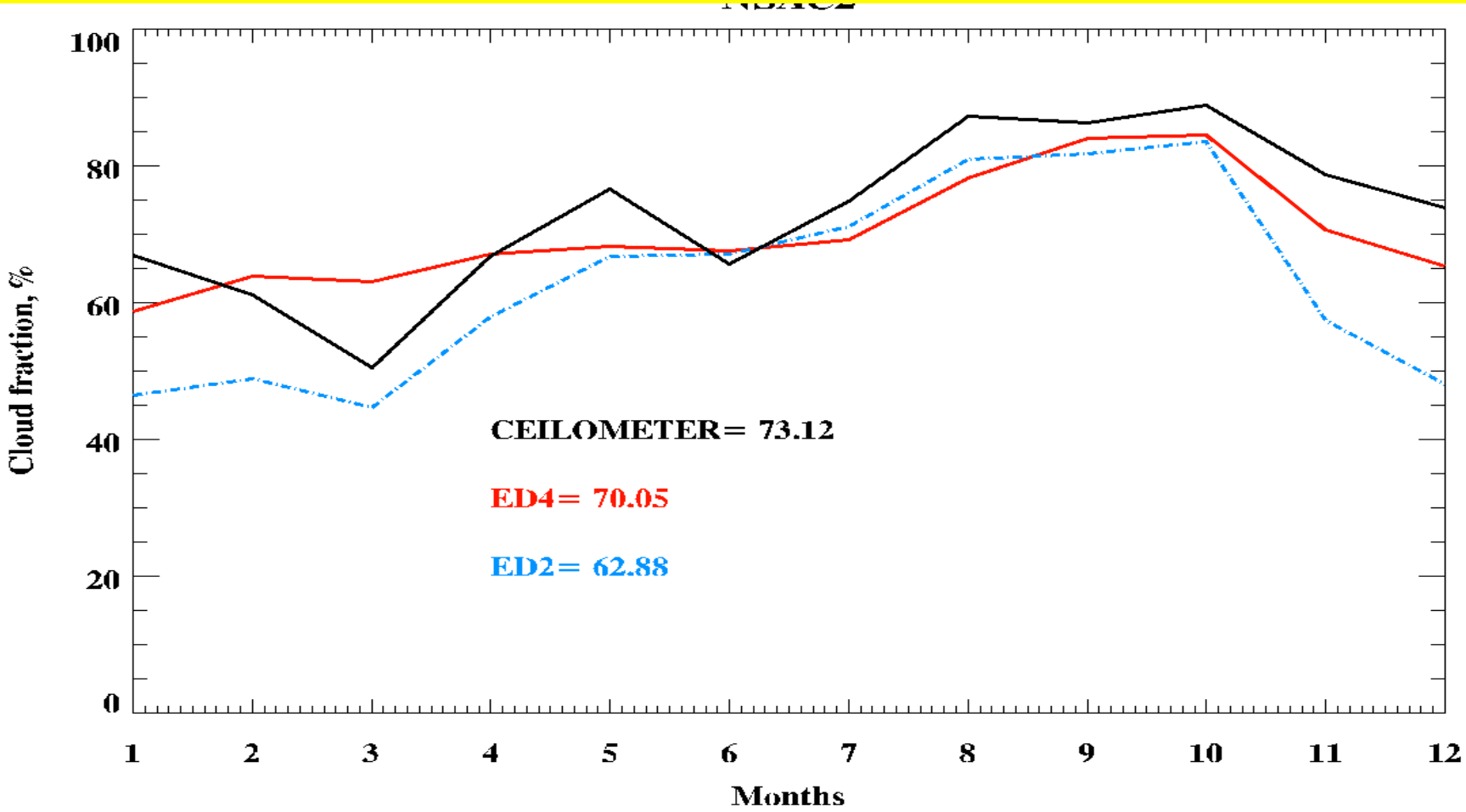


Though the cloud fraction is relatively low during March, ceilometer observed clouds agree well with the cloud radar measurements, so the cloud fraction from ceilometer is reliable.



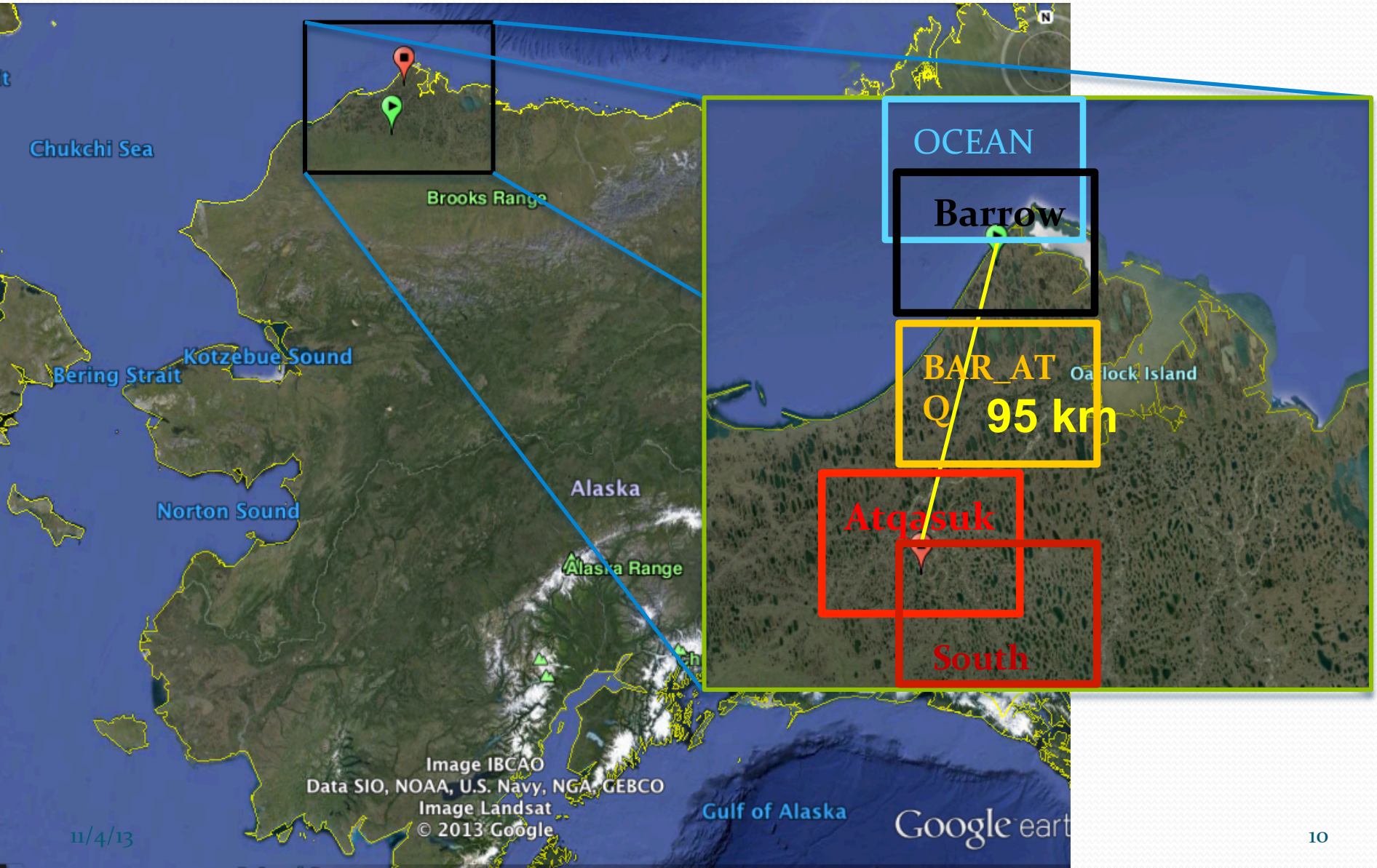


Comparing ceilometer-derived CFs with CERES-MODIS Ed4 and Ed2 CFs at Atqasuk site (2000-2003)

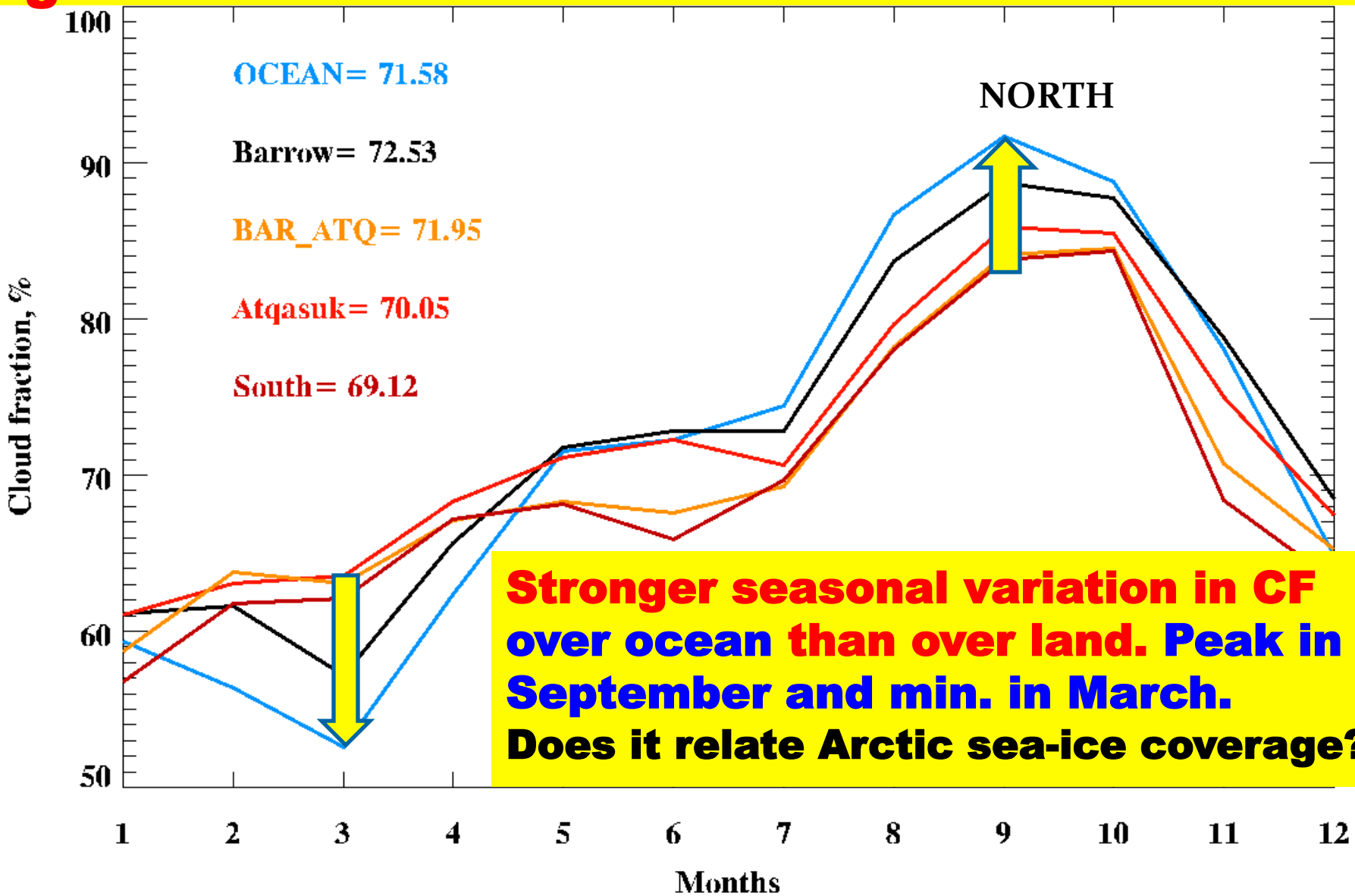


Same conclusion as that at Barrow site except for the CF difference between ARM and Ed4 is ~3%, still ~10% higher than Ed2 CFs.

How do CFs change from Ocean (north) to inland (south): 5 grid boxes from North to South



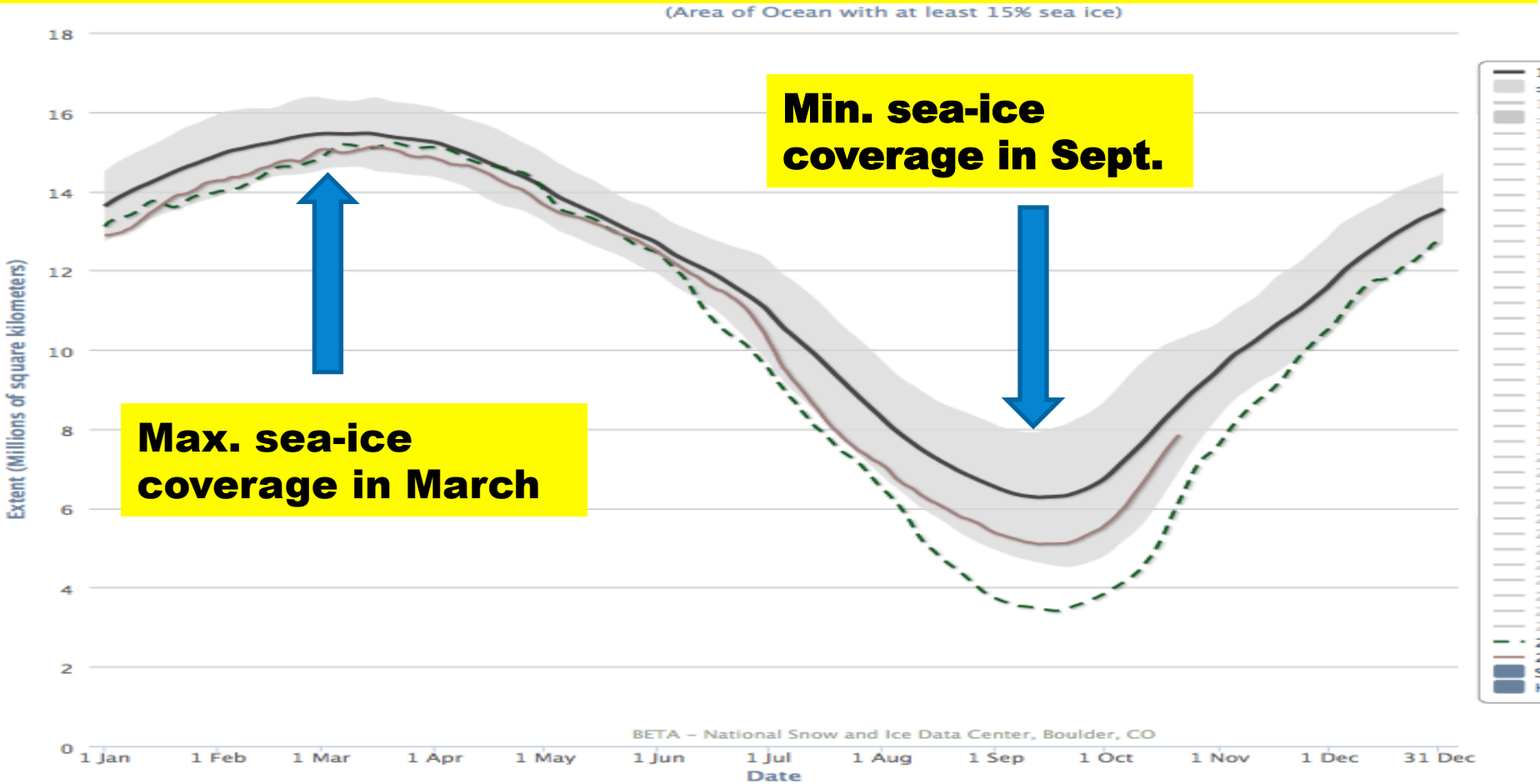
CFs change from Ocean (north) to inland (south): 5 grid boxes from North to South



Stronger seasonal variation in CF over ocean than over land. Peak in September and min. in March.

Does it relate Arctic sea-ice coverage?

Seasonal variation of Arctic sea-ice coverage



Strong negative correlations between CFs and Arctic sea-ice coverages indicate that water vapor is one of the reasons to lead to strong seasonal variation in CF, particular for CFs over 2 grid boxes (Ocean and Barrow).

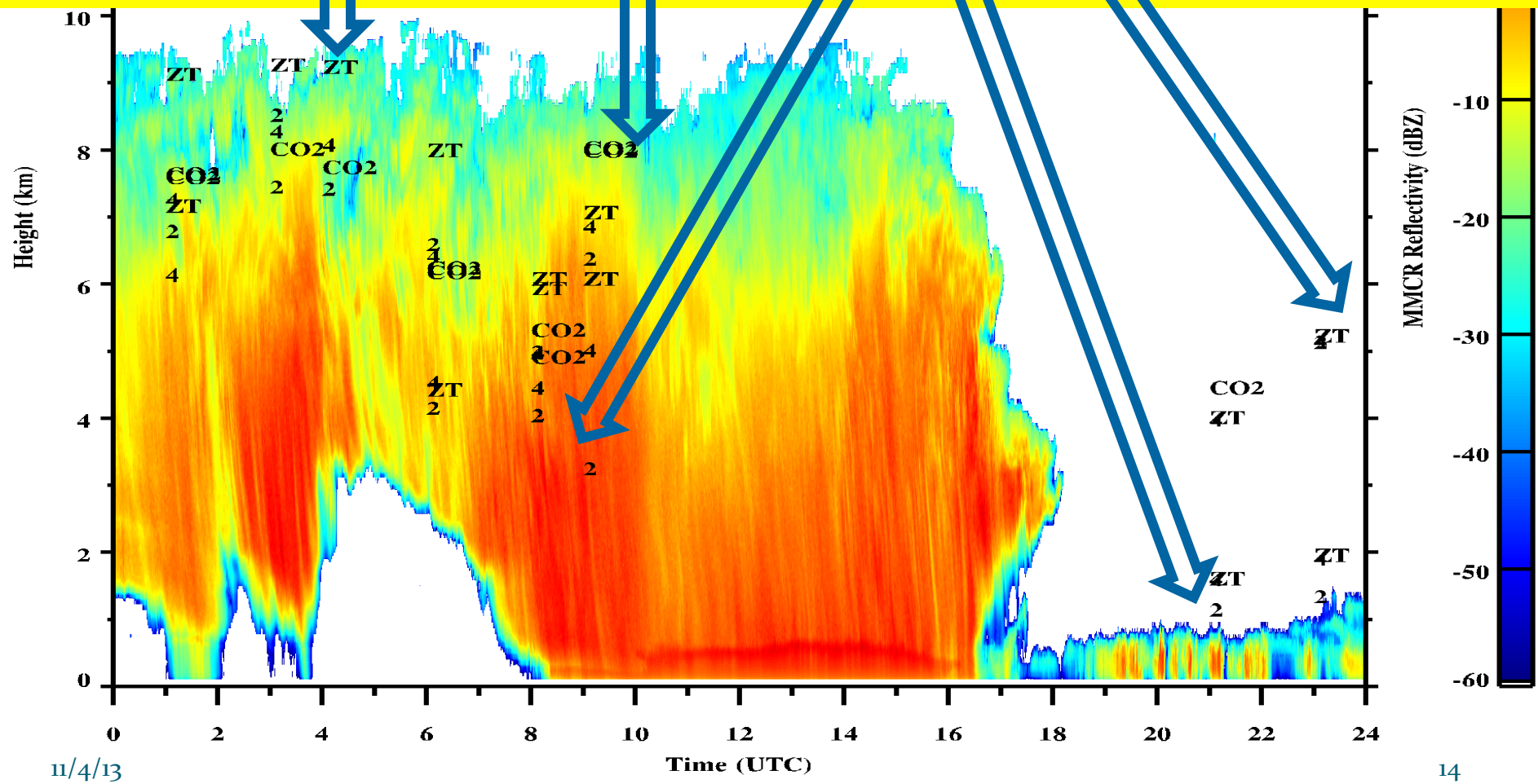
Sea ice data source: National Snow and Ice Data Center

Comparing Ed4 and Ed2 derived cloud heights with ARM radar measurements

- **Ed4 cloud-top height ZT (single and multilayer)**
- **Ed4 effective height Zeff derived from T_{eff} method and from CO_2 slicing technique;**
- **Ed2 effective height;**

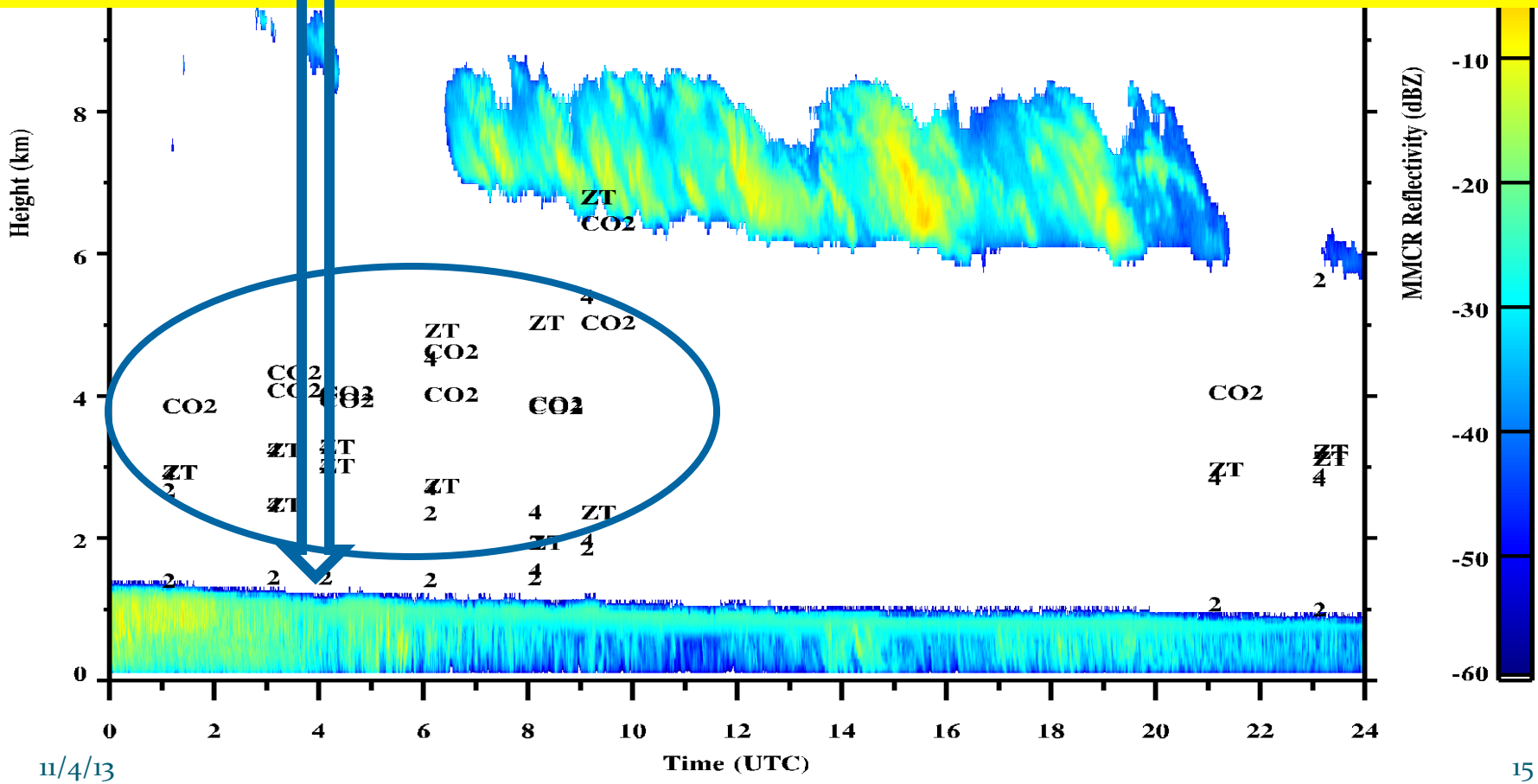
We will show four cases from the following four types of clouds to do detailed comparison:
(1) Deep clouds;
(2) Two-layer clouds;
(3) Multilayered clouds (layers>2);
(4) Low-level stratus clouds.

→Ed4 derived Cloud-top heights (ZT) are close to radar derived Ztop for deep clouds, but too high over the low-level clouds at 21Z and 23Z
→The effective heights by using CO_2 slicing tech. are higher than these derived from brightness temperature. For deep clouds, they look reasonable.
→The Ed4 effective heights derived from brightness temp. are higher than Ed2, but Ed4 are not reasonable for low clouds.
→Ed2 effective heights are much lower for deep clouds, at 21Z and 23Z close the radar low-level cloud tops.



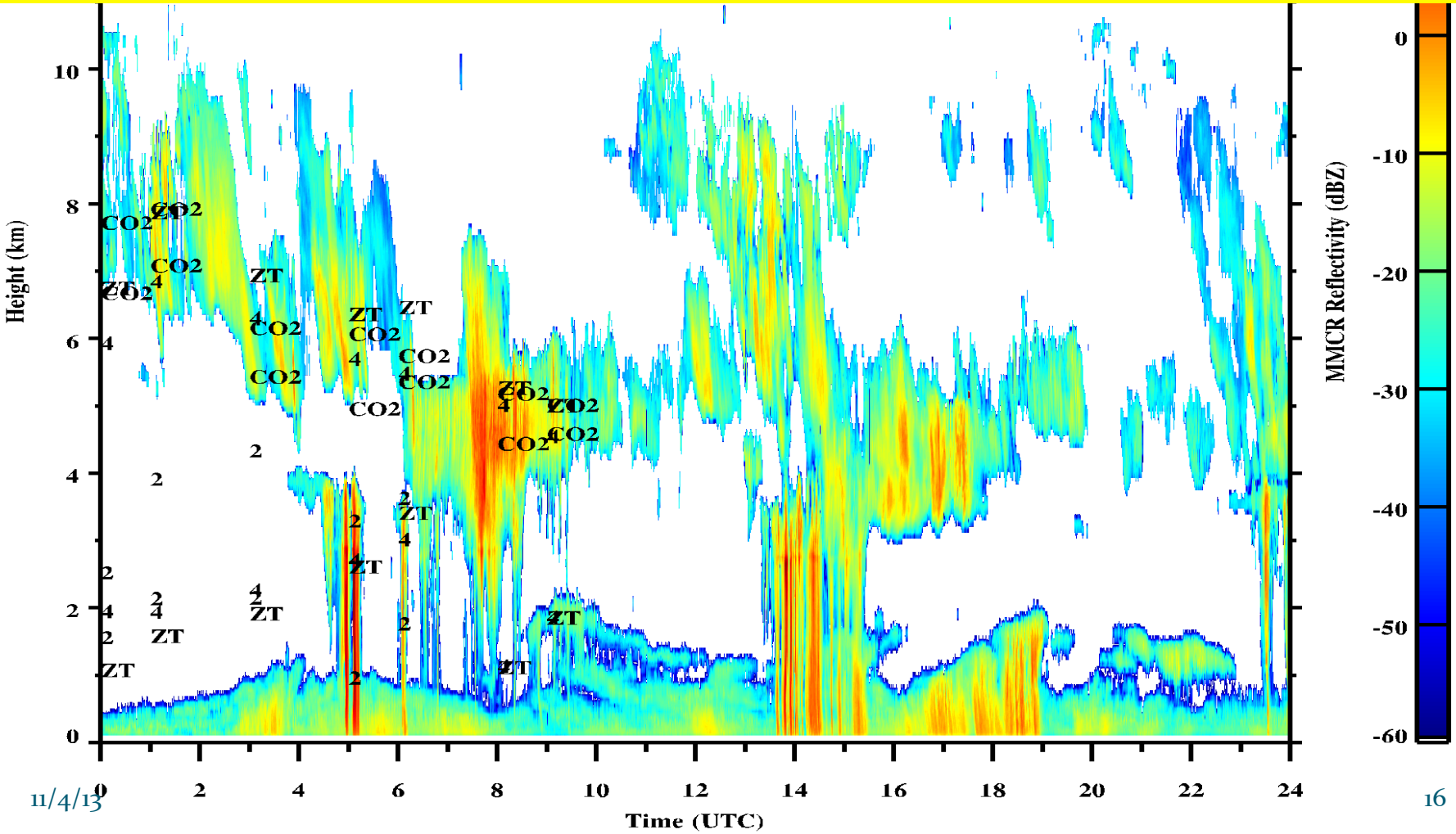
Cirrus over stratus clouds:

- **Most cloud-top heights ZT and effective heights fall between cirrus layer and low-level clouds (radar images)**
- **The Ed2 derived effective heights are close to low-level radar cloud tops.**



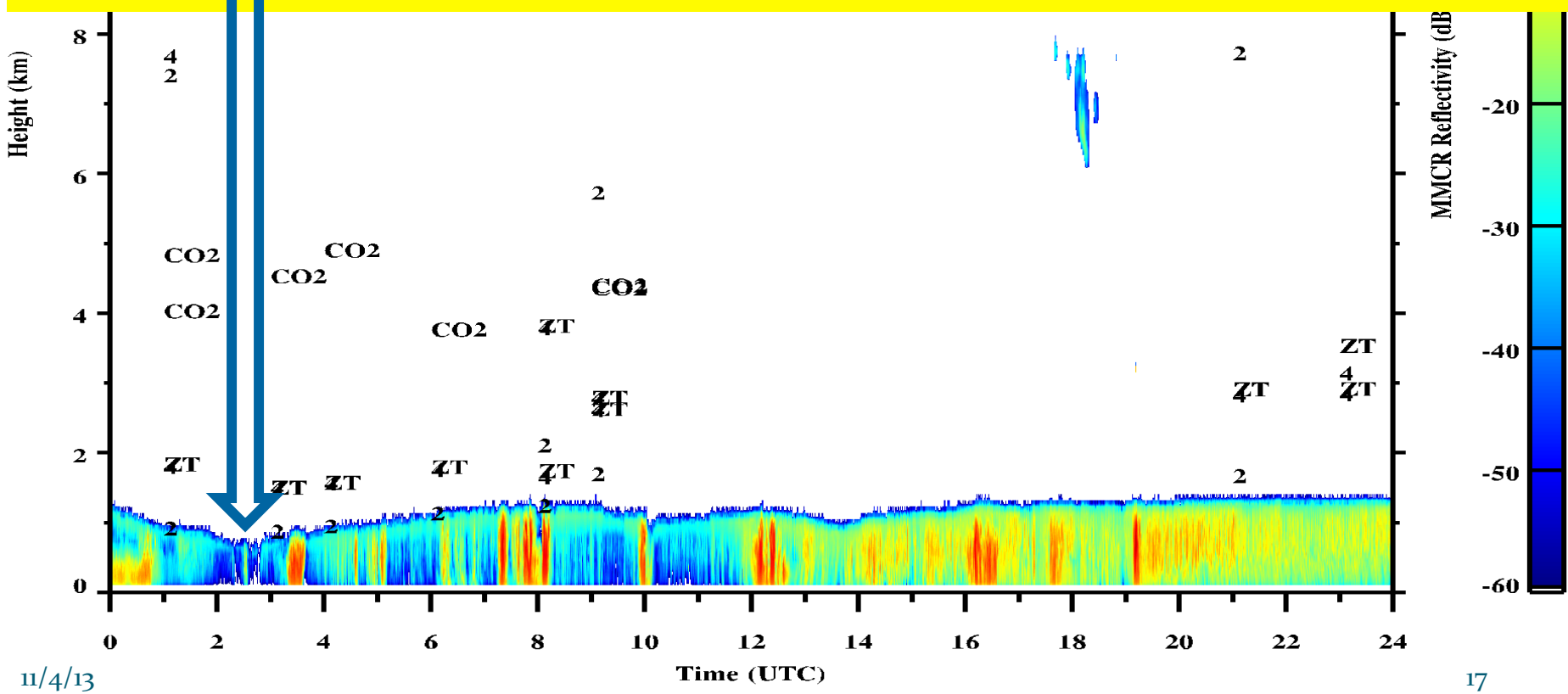
Multilayered clouds:

- **Ed4 derived ZT are OK compared to radar images, but slightly higher for lower cloud layer.**
- **The effective heights derived from CO_2 slicing tech. are higher than these derived from brightness temperature. For these multilayered clouds, they look reasonable.**
- **Ed2 effective heights fall between high and low cloud layers**

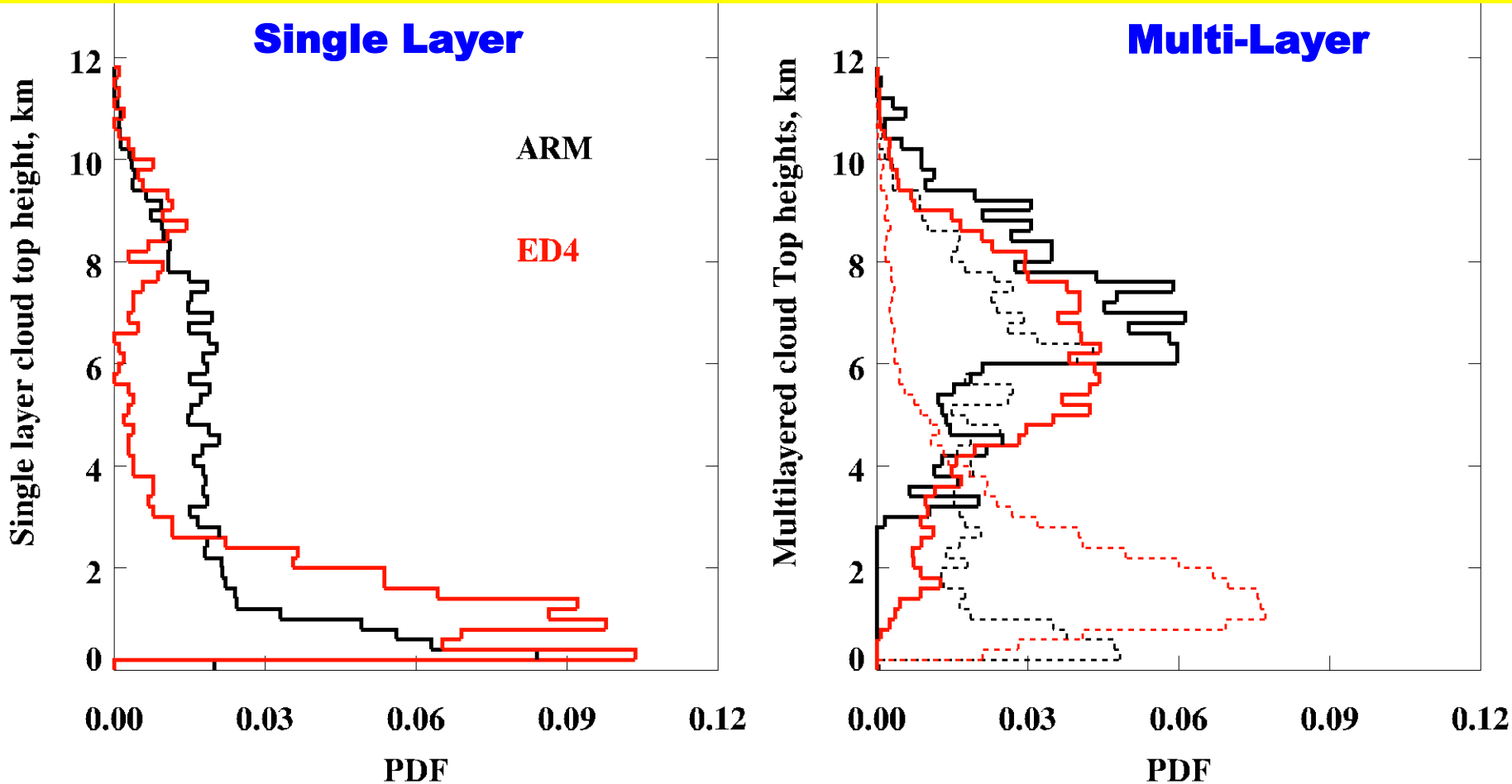


Stratus clouds:

- **Cloud-top heights (ZT) derived from Ed4 and Zeff from CO2 slicing tech. are too high compared to radar images.**
- **The Ed2 and Ed4 effective heights derived from brightness temp. are more or less close to radar derived cloud tops.**



Single-/multi- layered cloud-top height comparison between radar and Ed4



Single Layer: **Ed4 has 2 peaks at 1 km and 9 km, respectively.**
Multi-layer: **Ed4 has similar bi-modal distribution** **as radar observations.** **The higher one (solid line)** **is consistent to radar, but** **lower peak (dashed line)** **is about 1 km higher than radar**

Conclusions

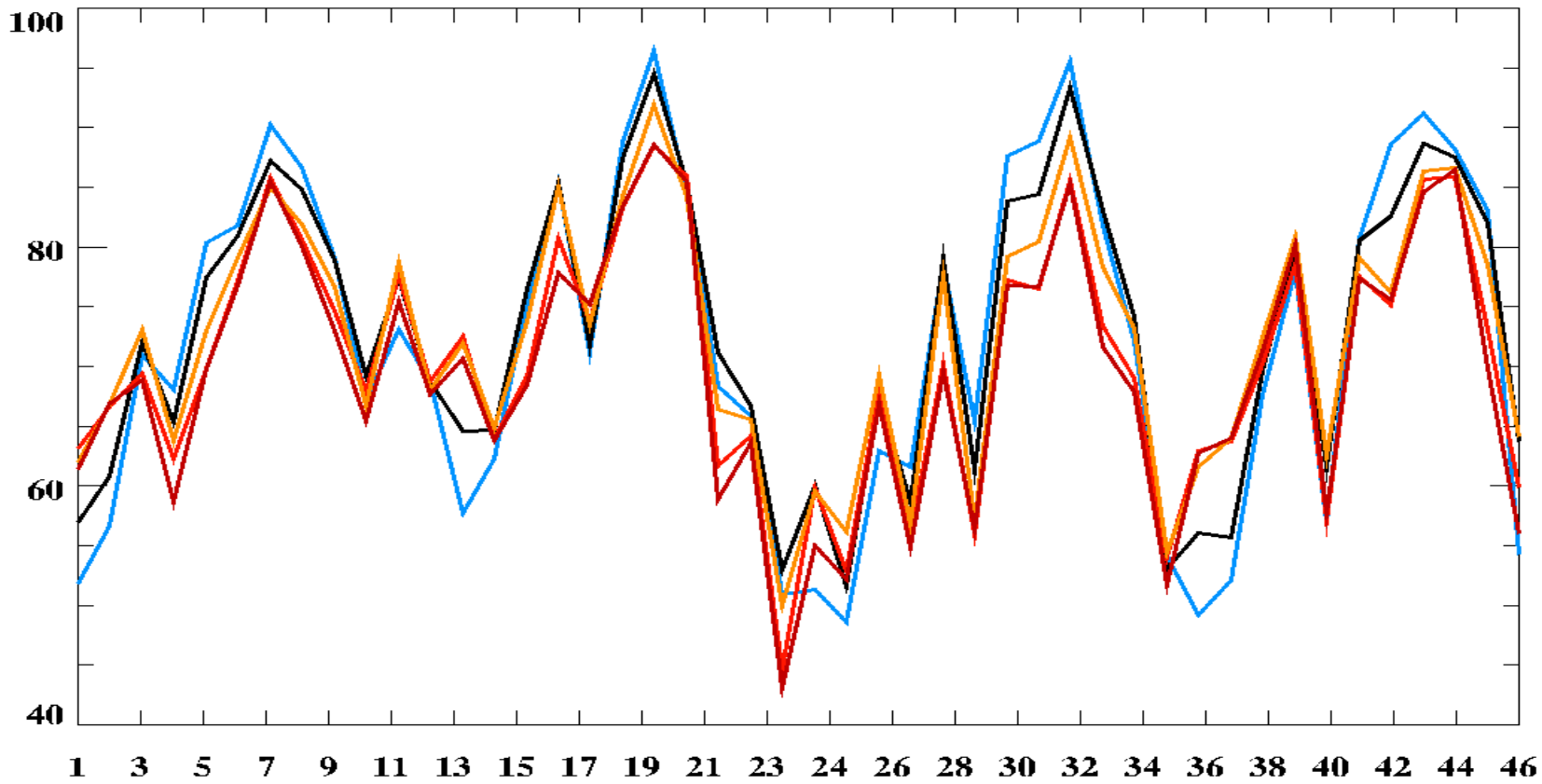
Cloud Fraction (CF)

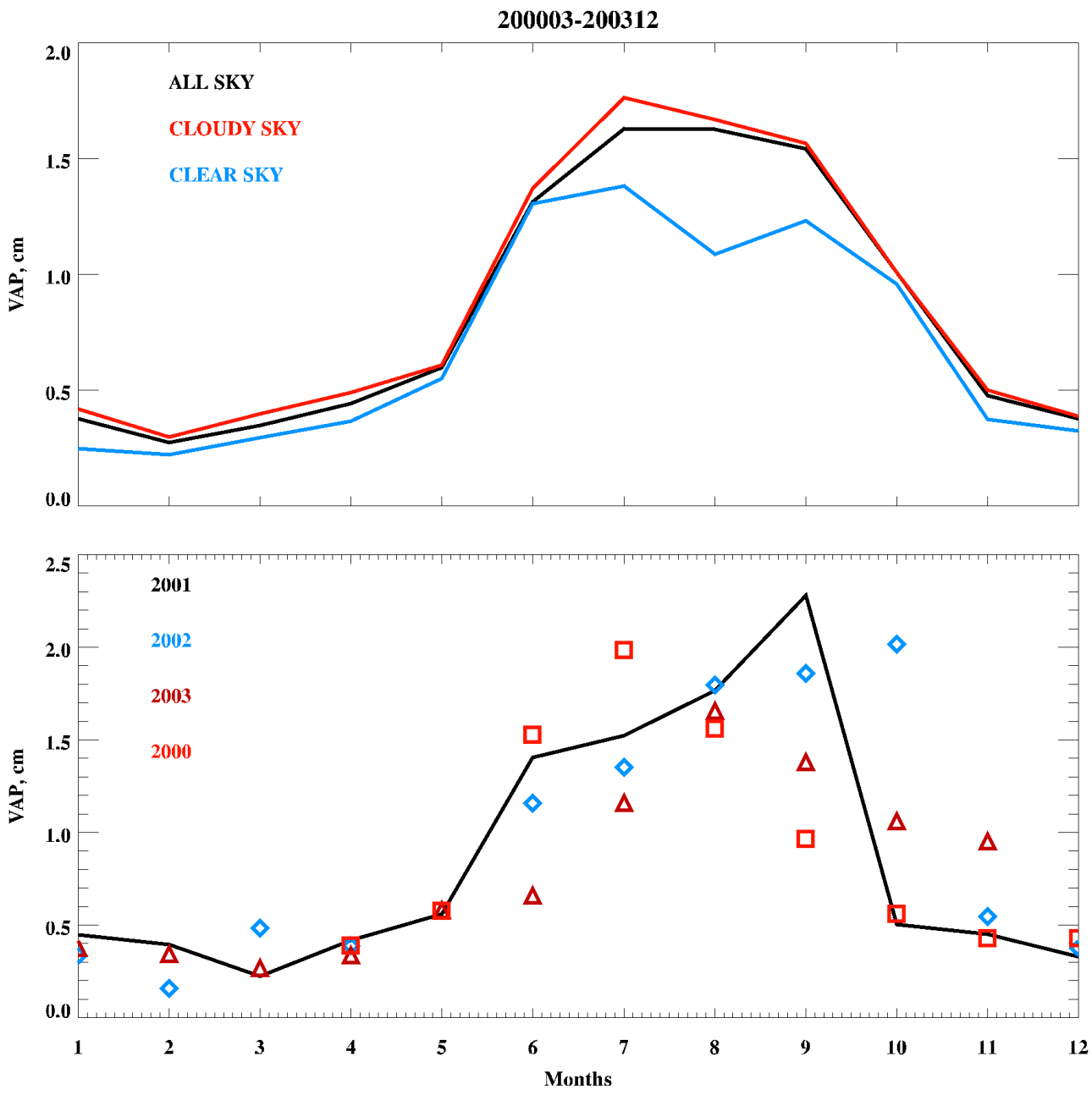
- Ed4 derived CFs are nearly the same as ceilometer derived CFs at both Barrow and Atqasuk,
- Ed4 makes significant improvement in CF retrievals, especially during polar night and over the snow/ice surfaces compared to Ed2.
- Improvement needed: Ed4 CFs are still lower during summer months than ceilometer CFs.

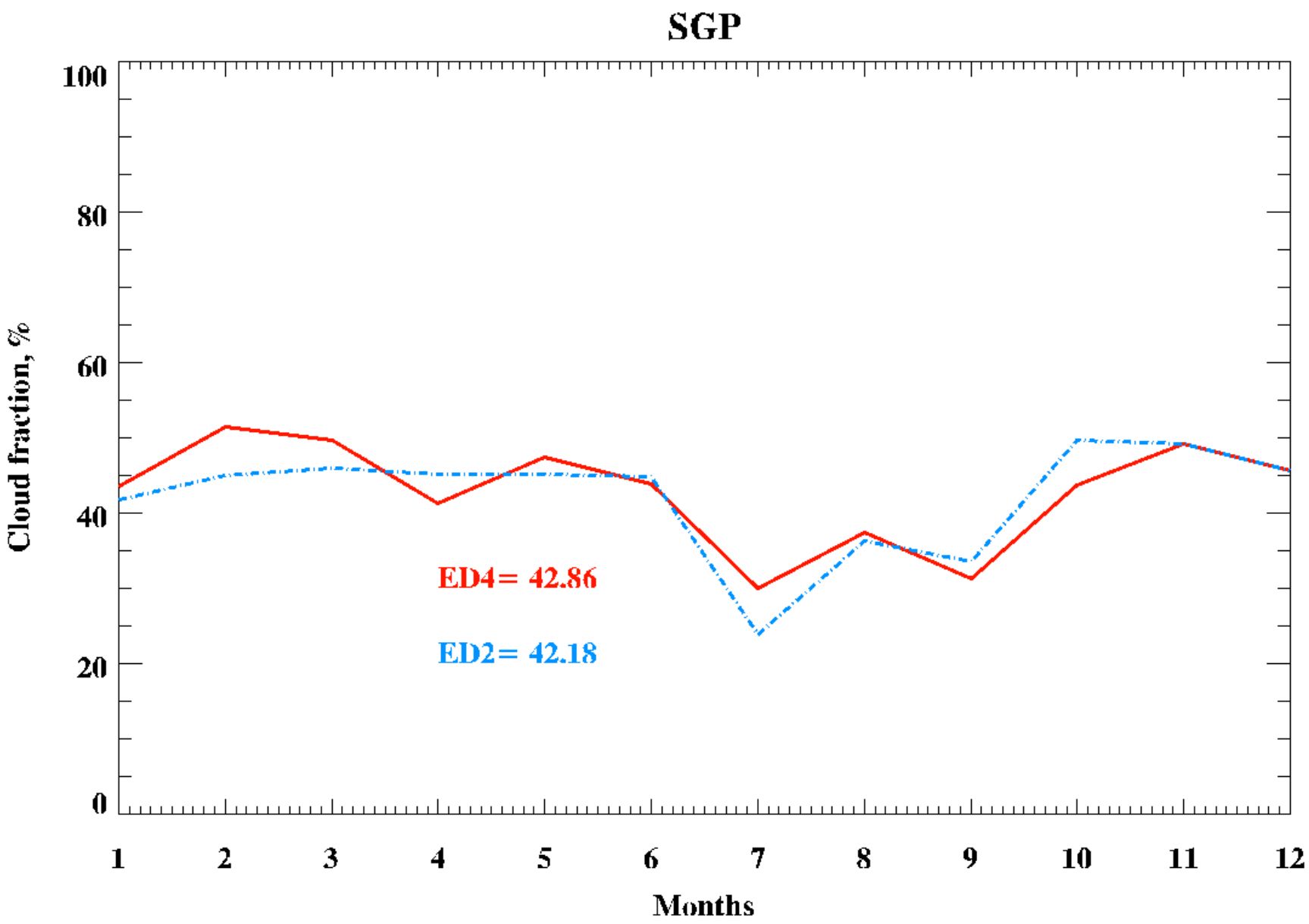
Cloud-top height Zt and effective height Zeff

- Cloud-top height ZT derived Ed4 and Zeff from CO2 slicing tech. agree well with radar cloud tops for deep and multi-layered clouds,
- while Ed4 and Ed2 effective heights derived from brightness temperatures agree well for low-level clouds.

Backup


100
80
60
40
1
3
5
7
9
11
13
15
17
19
21
23
24
26
28
30
32
34
36
38
40
42
44
46


200003-200312
ALL SKY
CLOUDY SKY
CLEAR SKY
VAP, cm
2.0
1.5
1.0
0.5
0.0
2001
2002
2003
2000
VAP, cm
2.5
2.0
1.5
1.0
0.5
0.0
1
2
3
4
5
6
7
8
9
10
11
12
Months


SGP
Cloud fraction, %
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
Months
ED4= 42.86
ED2= 42.18