Cloud Cover Validation using Ground Measurements

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Validation Database System

- Database of ground instrumen
  multiple sites
- Modular software matches sat
  with ground instruments
- Supports multiple cloud masks
- Batch and Interactive
- Standard netCDF output forma

Current Validation Sites

- Atmospheric Radiation Measurement Prog

- Explorer of the Seas cruise ship - S.E. Atlantic, Caribbean Sea

ARM Instruments

Vaisala Ceilometer
Model CT25k (VCEIL)

Millimeter Wav
Cloud Radar (

Micropulse Lidar (MPL)

Whole Sky Ir

Cruise Ship Instruments

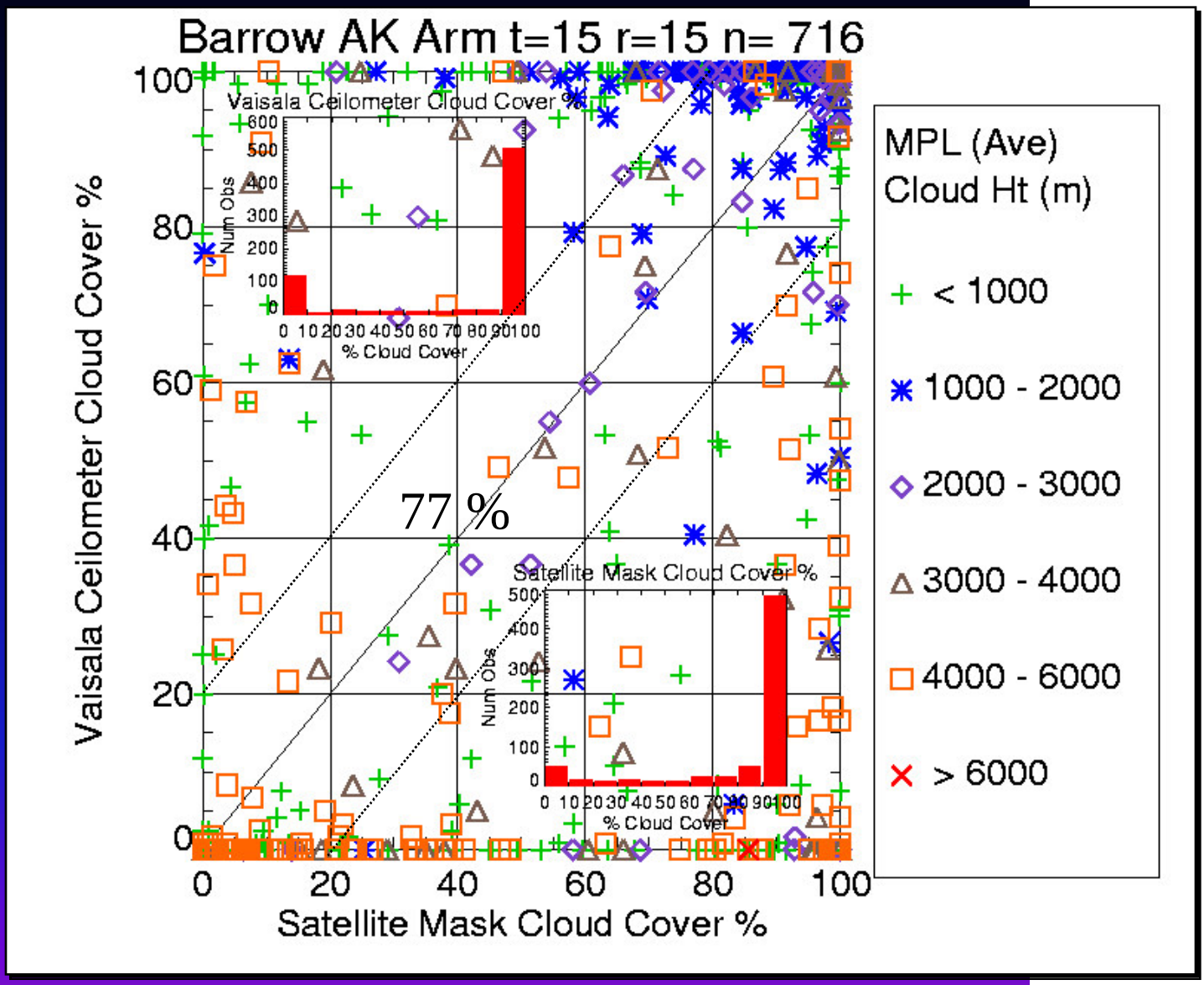
Vaisala Ceilometer, Total Sky Image

Instrument Data

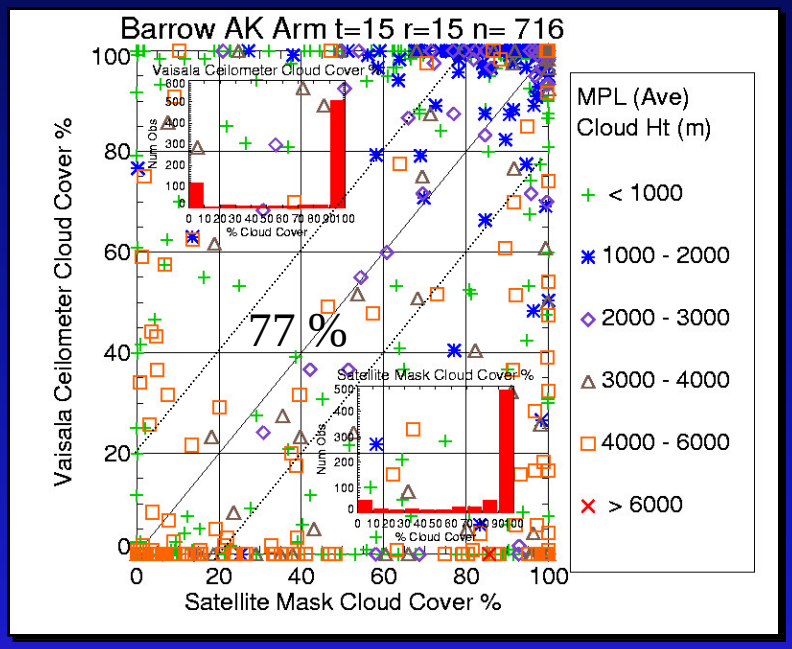
- Cloud cover +/- 15 min of overp
  - Vaisala Ceilometer
  - Micropulse Lidar
  - Millimeter Wavelength Cloud Rad
  - Active Remote Sensing of Cloud
- Whole / Total sky imager - dire
- Normal Incidence Pyrheliomete
  effective optical depth from Clir
  Monitoring & Diagnosis LAB (C

Validation of Cloud Masks

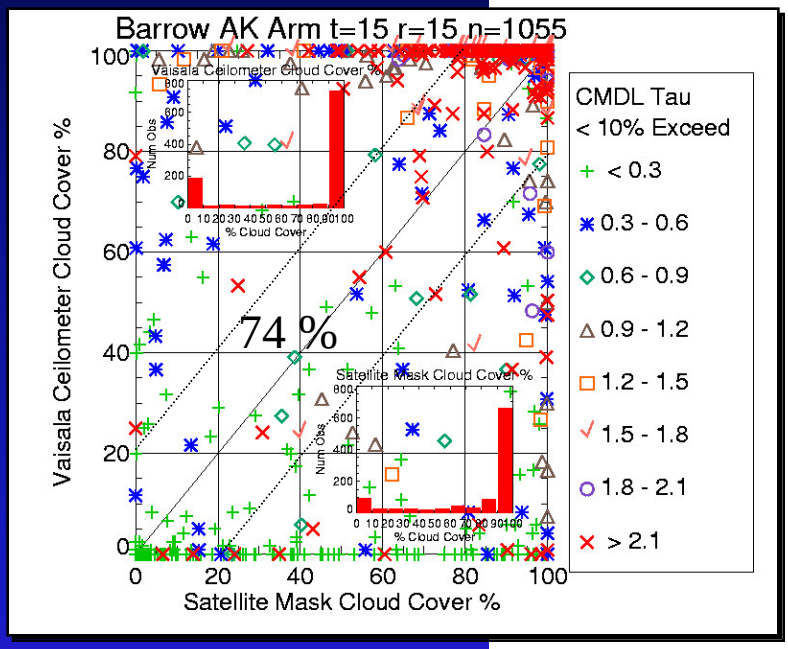
- Extract satellite data for ground and create cloud masks
- Extract matching surface data fo satellite overpass
- Compute cloud cover for satellit masks and ground instruments


Barrow AK Arm t=15 r=15 n= 716
Vaisala Ceilometer Cloud Cover %
Satellite Mask Cloud Cover %
77 %
Vaisala Ceilometer Cloud Cover %
Num Obs
% Cloud Cover
Satellite Mask Cloud Cover %
Num Obs
% Cloud Cover
MPL (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

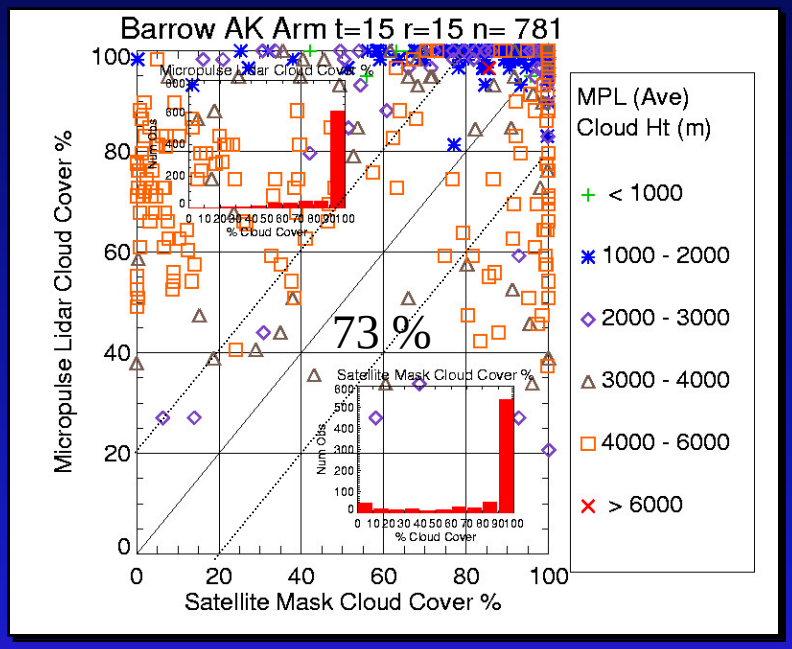
Height


Barrow AK Arm t=15 r=15 n= 716
Vaisala Ceilometer Cloud Cover %
Satellite Mask Cloud Cover %
77 %
MPL (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000
Num Obs
% Cloud Cover

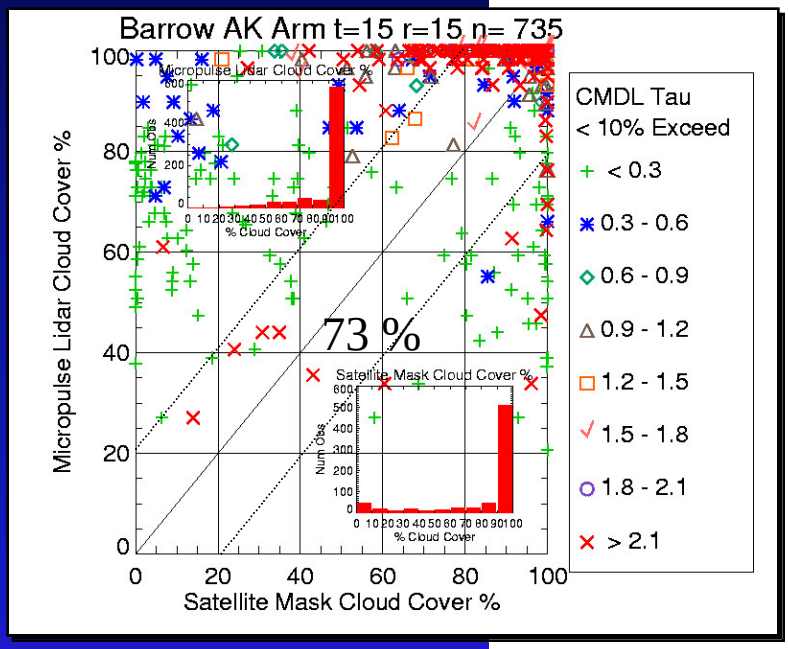
EOD


Barrow AK Arm t=15 r=15 n=1055
Vaisala Ceilometer Cloud Cover %
Satellite Mask Cloud Cover %
74 %
CMDL Tau
< 10% Exceed
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
1.2 - 1.5
1.5 - 1.8
1.8 - 2.1
> 2.1
Num Obs
% Cloud Cover

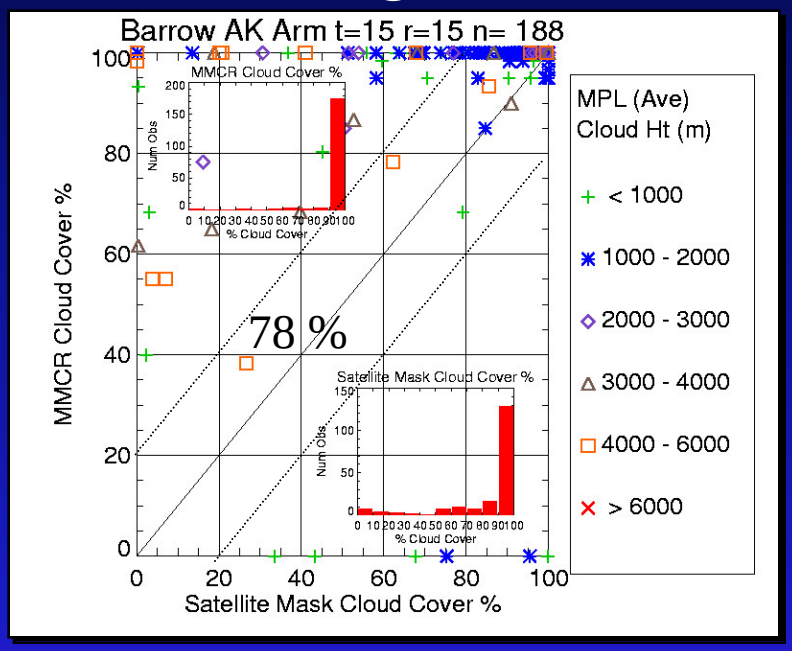
Height


Barrow AK Arm t=15 r=15 n= 781
Micropulse Lidar Cloud Cover %
Satellite Mask Cloud Cover %
73 %
MPL (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000
Num Obs
% Cloud Cover

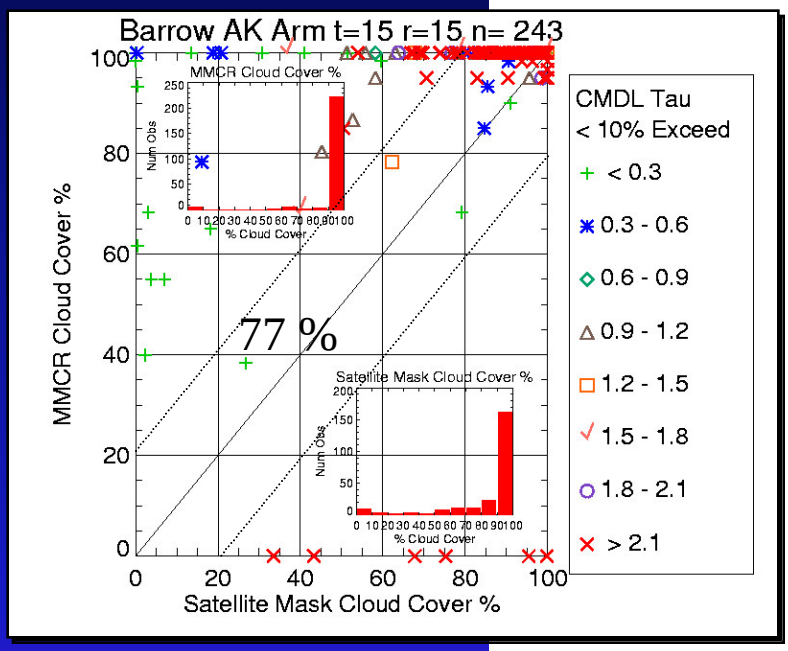
EOD


Barrow AK Arm t=15 r=15 n= 735
Micropulse Lidar Cloud Cover %
Satellite Mask Cloud Cover %
73 %
CMDL Tau
< 10% Exceed
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
1.2 - 1.5
1.5 - 1.8
1.8 - 2.1
> 2.1
Num Obs
% Cloud Cover

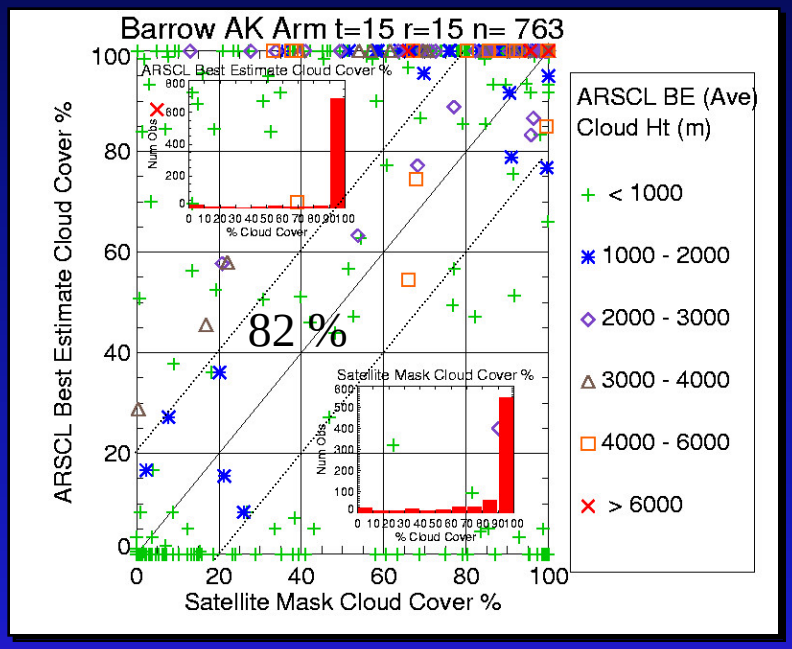
Height


Barrow AK Arm t=15 r=15 n= 188
MMCR Cloud Cover %
Satellite Mask Cloud Cover %
78 %
MPL (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000
Num Obs
% Cloud Cover

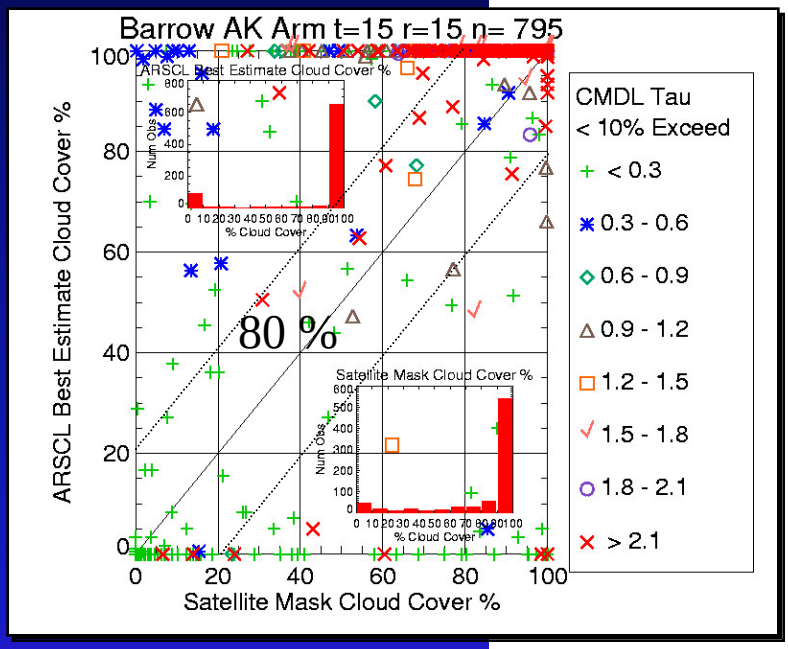
EOD


Barrow AK Arm t=15 r=15 n= 243
MMCR Cloud Cover %
Satellite Mask Cloud Cover %
77 %
CMDL Tau
< 10% Exceed
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
1.2 - 1.5
1.5 - 1.8
1.8 - 2.1
> 2.1
Num Obs
% Cloud Cover

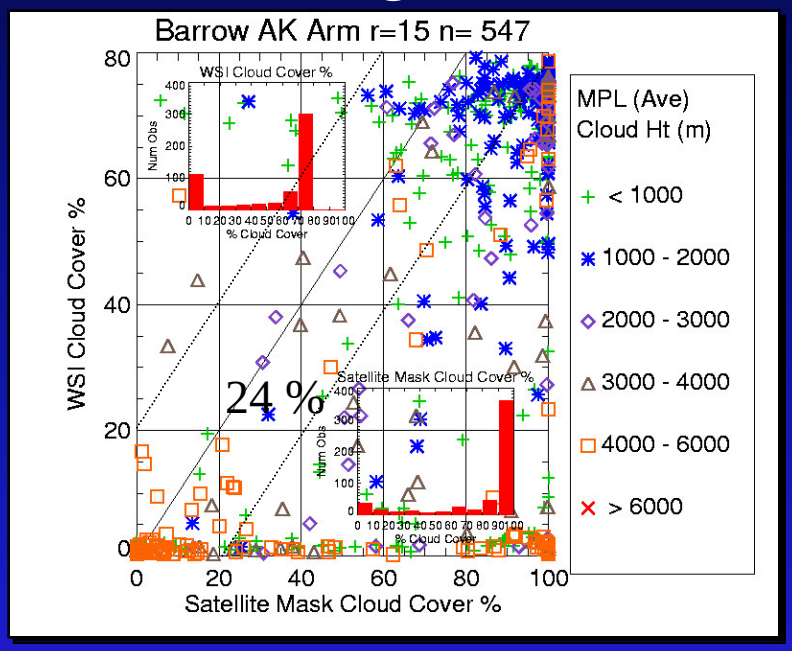
Height


Barrow AK Arm t=15 r=15 n= 763
ARSCL Best Estimate Cloud Cover %
Satellite Mask Cloud Cover %
82 %
Num Obs
% Cloud Cover
ARSCL BE (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

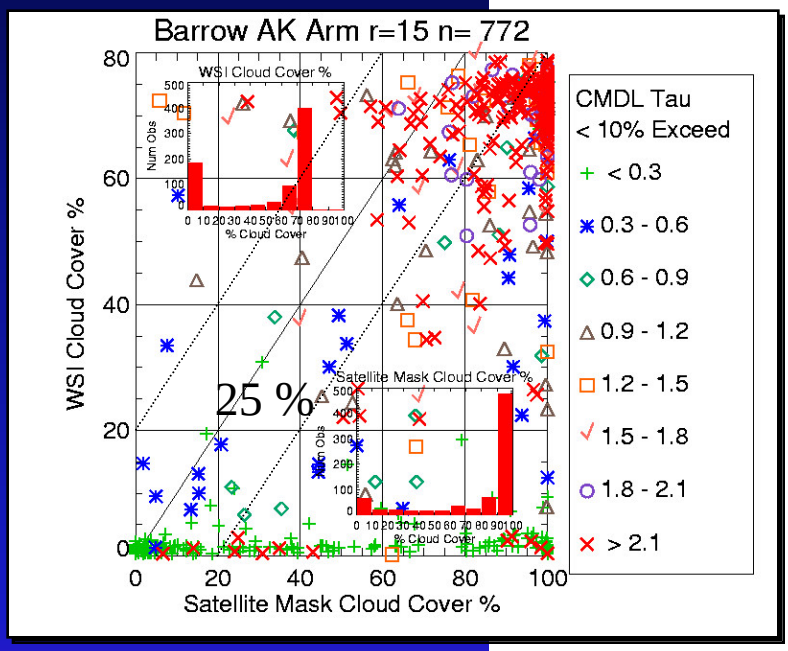
EOD

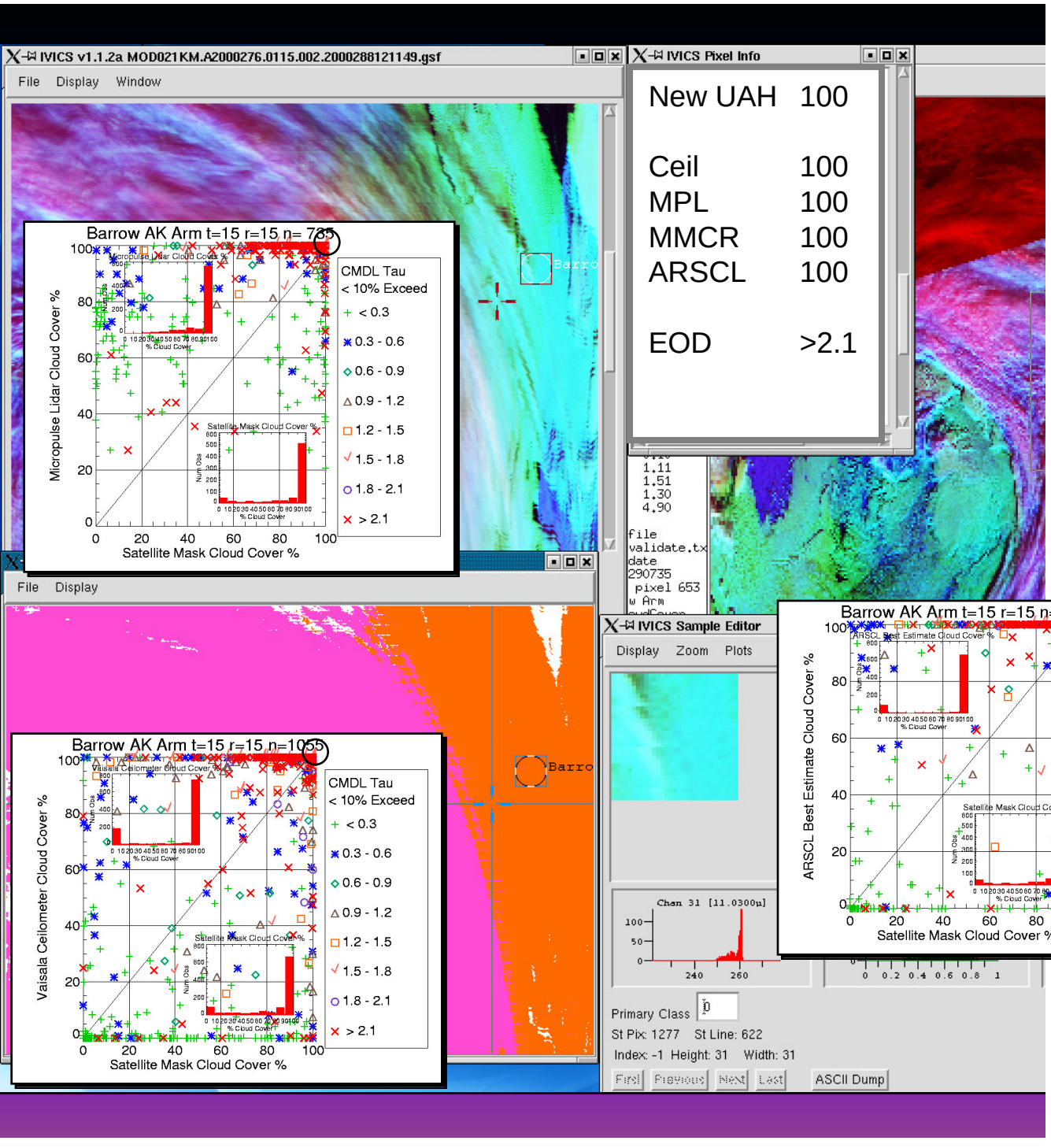

Barrow AK Arm t=15 r=15 n= 795
ARSCL Best Estimate Cloud Cover %
Satellite Mask Cloud Cover %
80 %
Num Obs
% Cloud Cover
CMDL Tau
< 10% Exceed
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
1.2 - 1.5
1.5 - 1.8
1.8 - 2.1
> 2.1

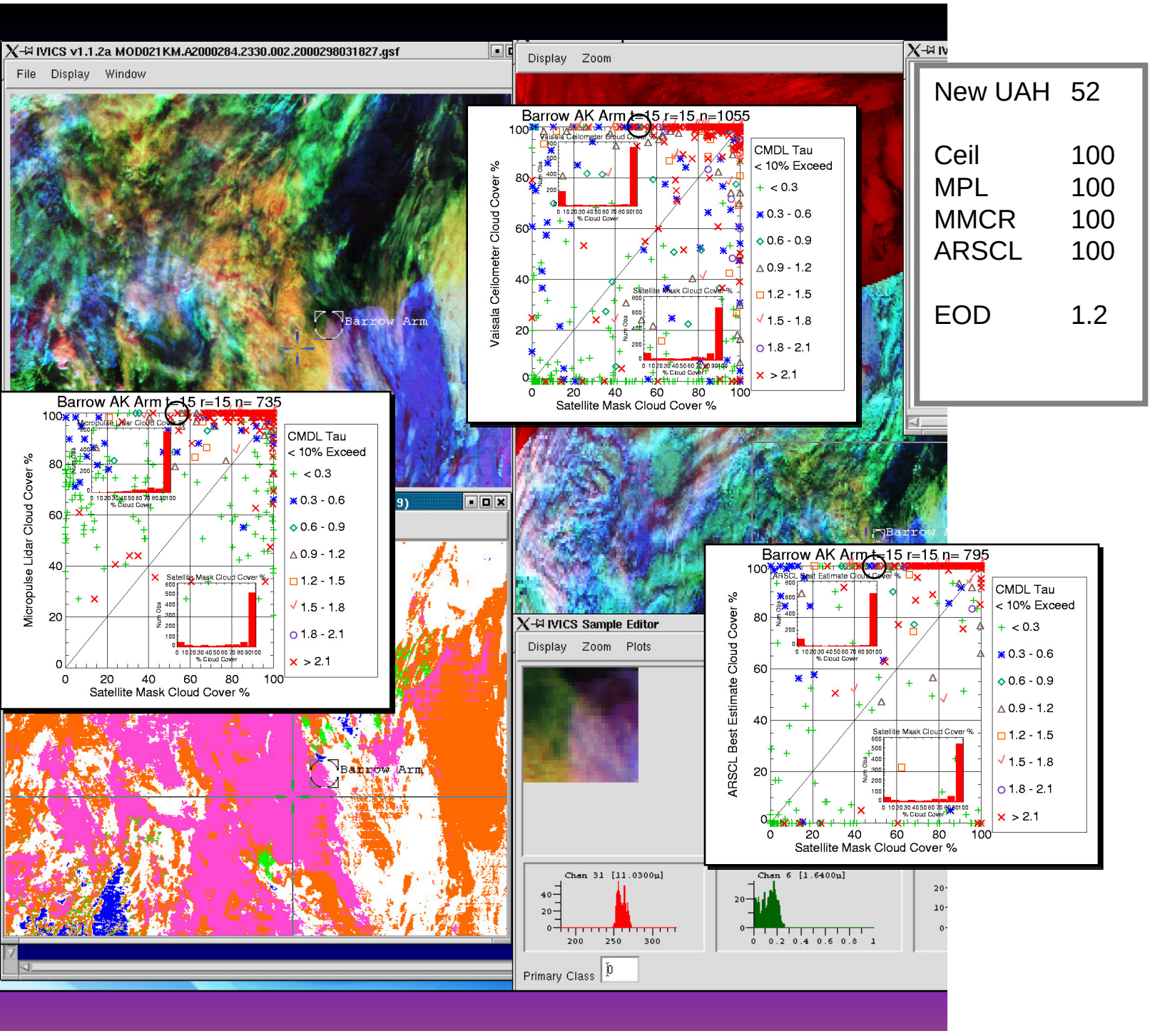
Height


Barrow AK Arm r=15 n= 547
WSI Cloud Cover %
Satellite Mask Cloud Cover %
24 %
MPL (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000
Num Obs
% Cloud Cover

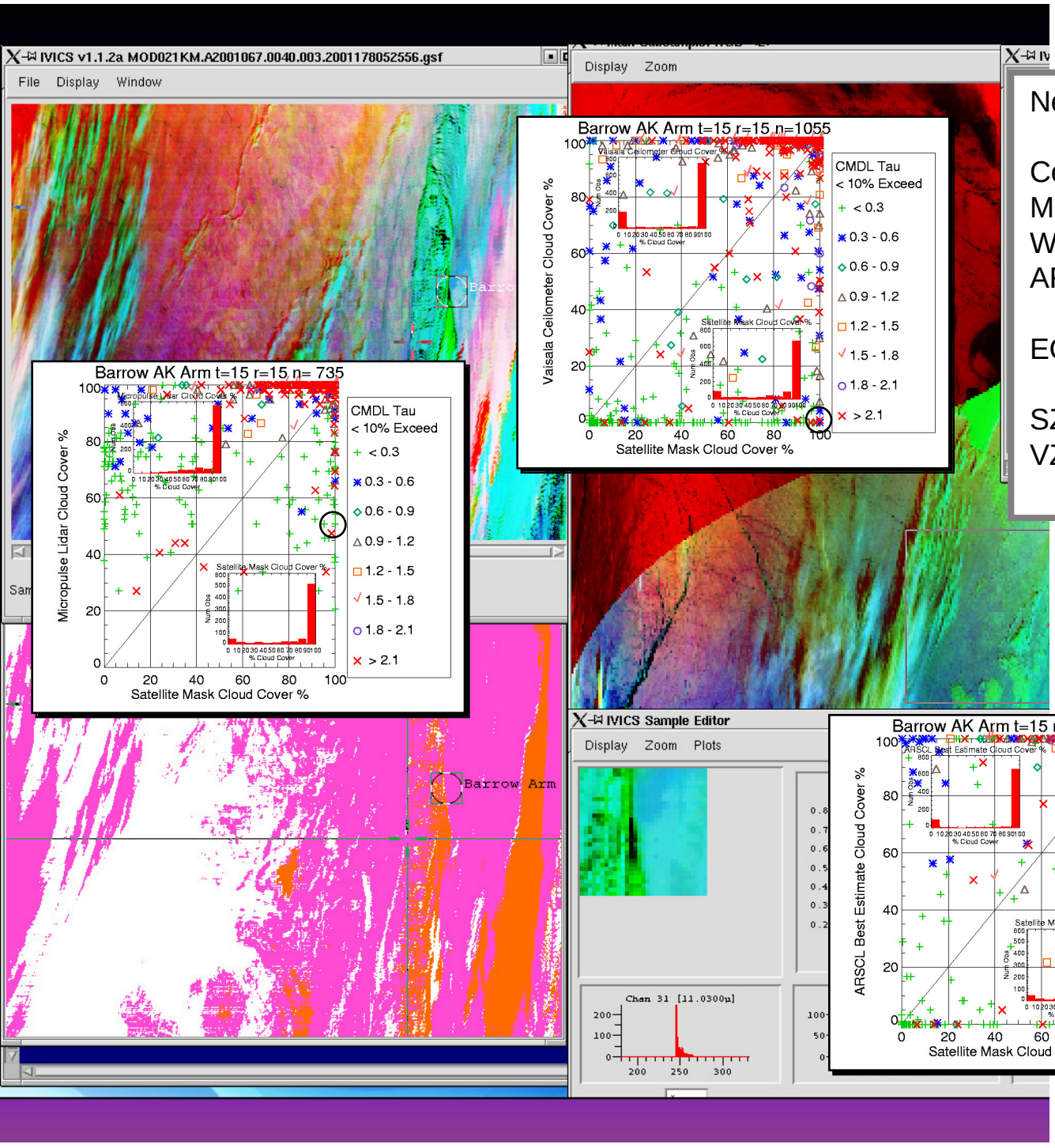
EOD


Barrow AK Arm r=15 n= 772
WSI Cloud Cover %
Satellite Mask Cloud Cover %
25 %
CMDL Tau
< 10% Exceed
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
1.2 - 1.5
1.5 - 1.8
1.8 - 2.1
> 2.1
Num Obs
% Cloud Cover

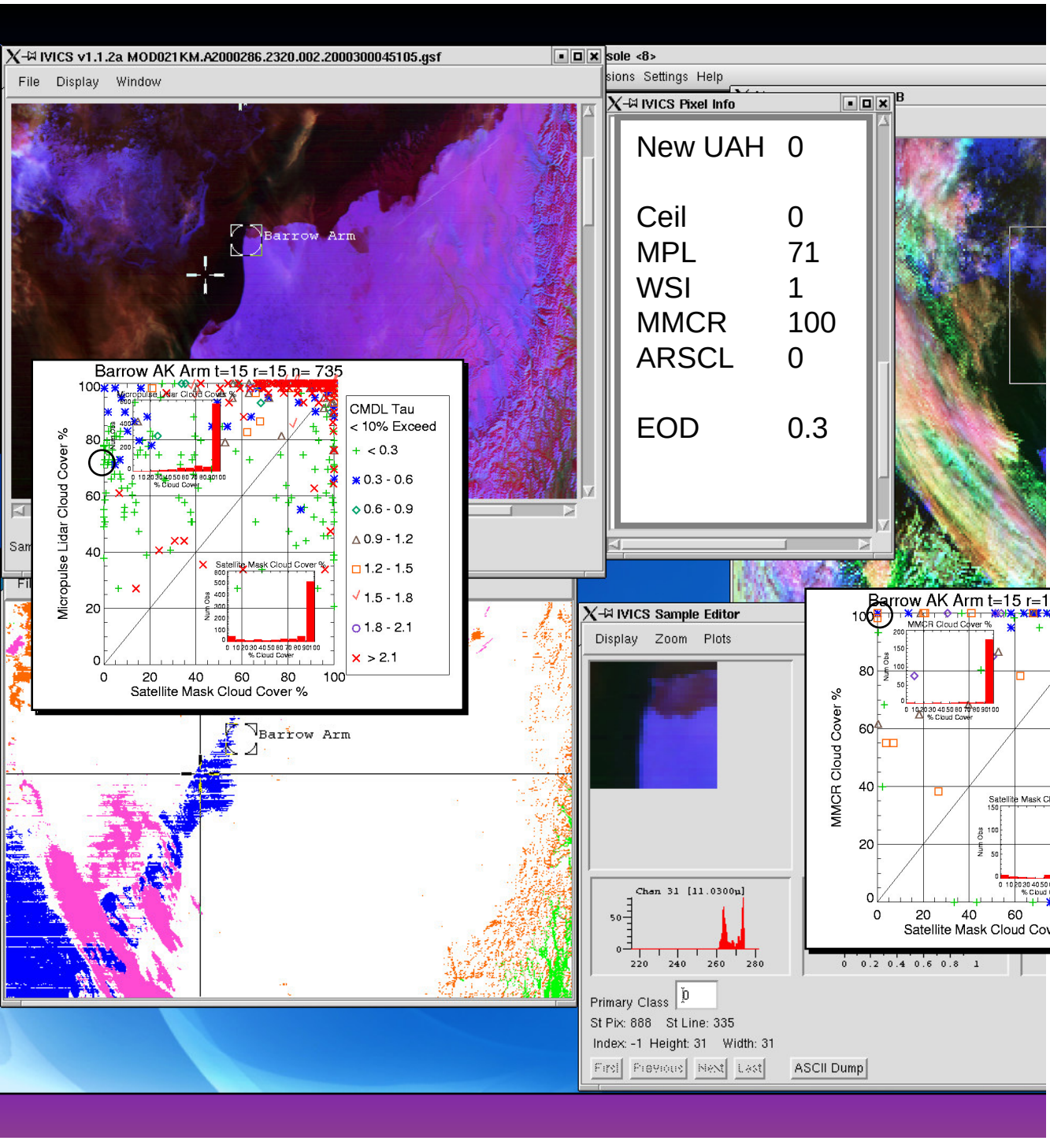

IVICS v1.1.2a MOD021KM.A2000276.0115.002.2000288121149.gsf
File Display Window
Barrow AK Arm t=15 r=15 n= 785
Micropulse Lidar Cloud Cover %
Satellite Mask Cloud Cover %
CMDL Tau
< 10% Exceed
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
1.2 - 1.5
1.5 - 1.8
1.8 - 2.1
> 2.1
IVICS Pixel Info
New UAH 100
Ceil 100
MPL 100
MMCR 100
ARSCL 100
EOD >2.1
1.11
1.51
1.30
4.90
file
validate.tx
date
290735
pixel 653
w Arm
File Display
Barrow AK Arm t=15 r=15 n=1055
Vaisala Ceilometer Cloud Cover %
Satellite Mask Cloud Cover %
IVICS Sample Editor
Display Zoom Plots
Chan 31 [11.0300u]
Primary Class
St Pix: 1277 St Line: 622
Index: -1 Height: 31 Width: 31
First Previous Next Last ASCII Dump
Barrow AK Arm t=15 r=15 n= 785
ARSCL Best Estimate Cloud Cover %
Satellite Mask Cloud Cover %



New UAH	52
Ceil	100
MPL	100
MMCR	100
ARSCL	100
EOD	1.2



New UAH	100
Ceil	0
MPL	50
WSI	3
ARSCL	0
EOD	0.3
SZ	70
VZ	55

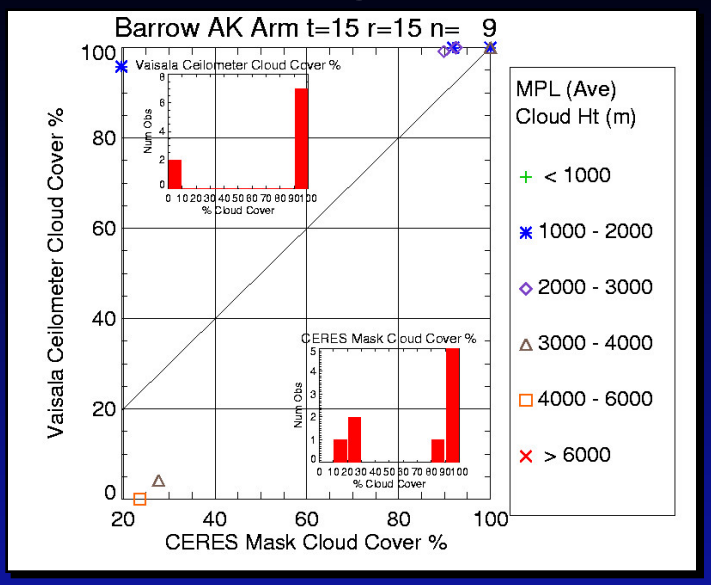

IVICS v1.1.2a MOD021KM.A2000286.2320.002.2000300045105.gsf
File Display Window
Barrow Arm
IVICS Pixel Info
New UAH 0
Ceil 0
MPL 71
WSI 1
MMCR 100
ARSCL 0
EOD 0.3
Barrow AK Arm t=15 r=15 n= 735
Micropulse Lidar Cloud Cover %
Satellite Mask Cloud Cover %
CMDL Tau
< 10% Exceed
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
1.2 - 1.5
1.5 - 1.8
1.8 - 2.1
> 2.1
Barrow Arm
IVICS Sample Editor
Display Zoom Plots
Chan 31 [11.0300μ]
Primary Class
St Pix: 888 St Line: 335
Index: -1 Height: 31 Width: 31
First Previous Next Last ASCII Dump
Barrow AK Arm t=15 r=15 n= 188
MMCR Cloud Cover %
Satellite Mask Cloud Cover %
MPL (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

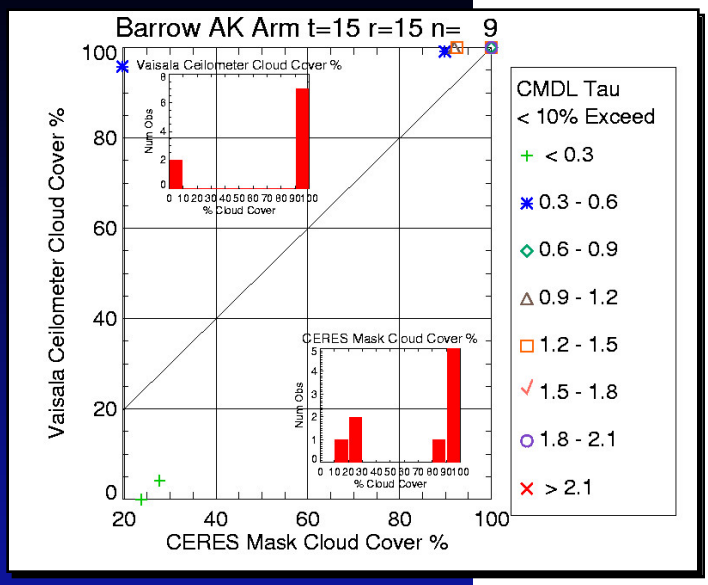
Height

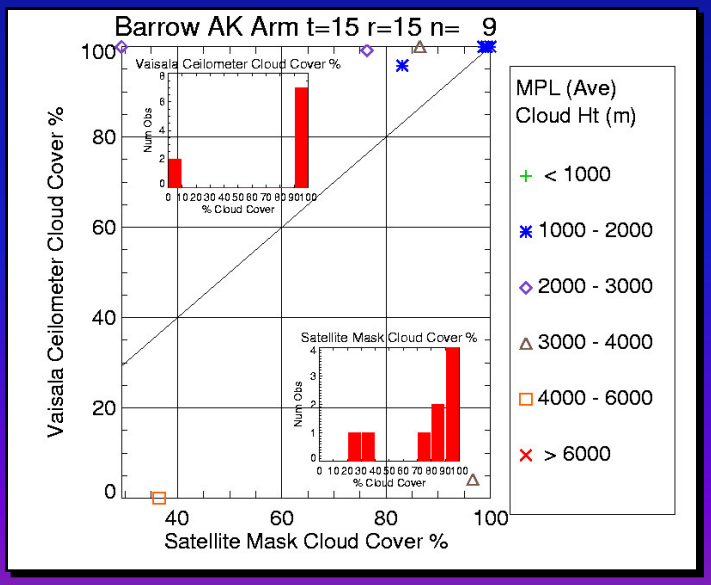
EOD

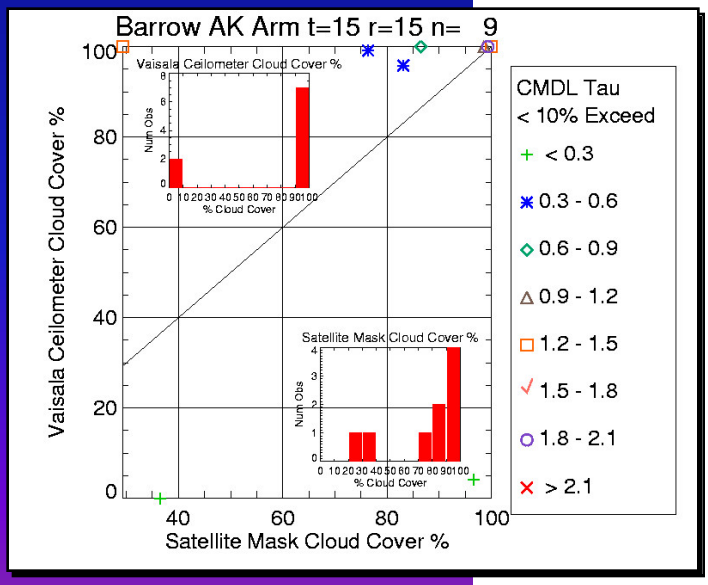
ES

H







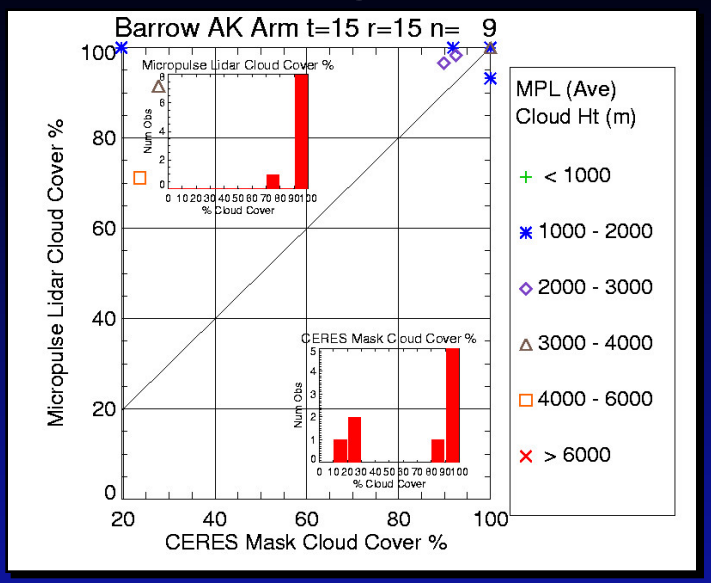


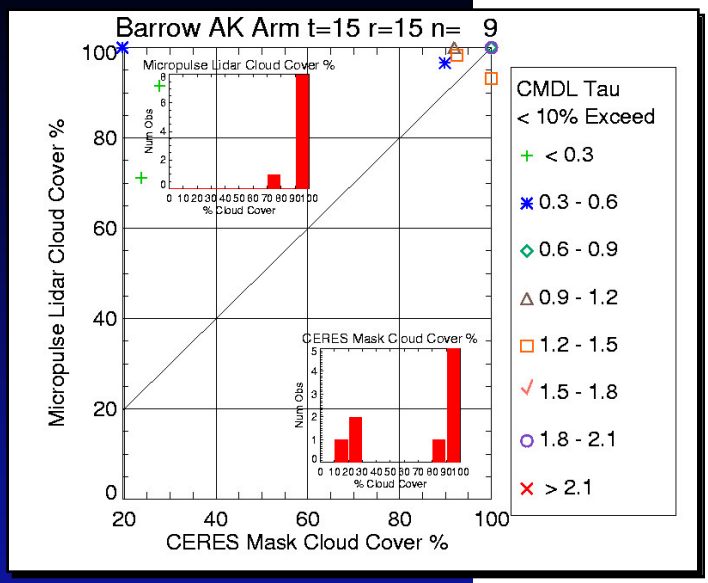
Height

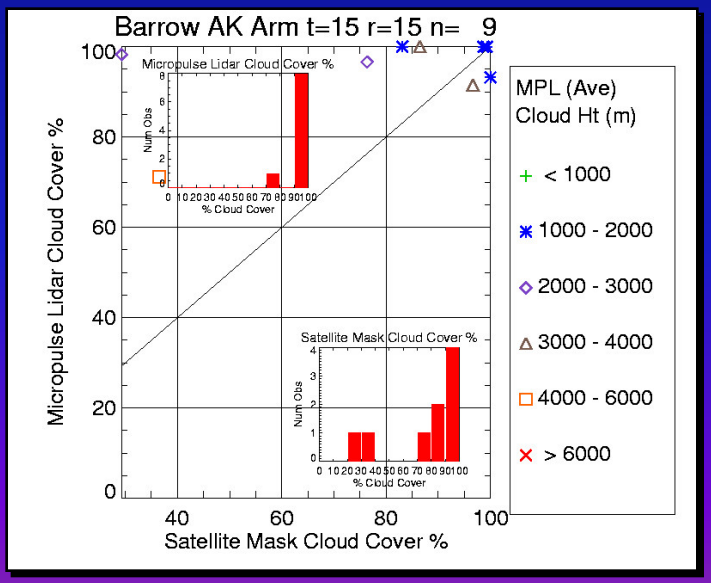
EOD

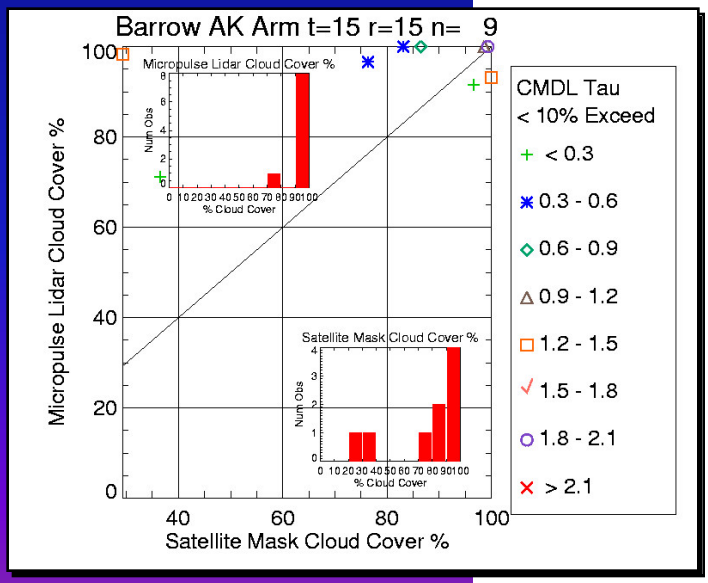
ES

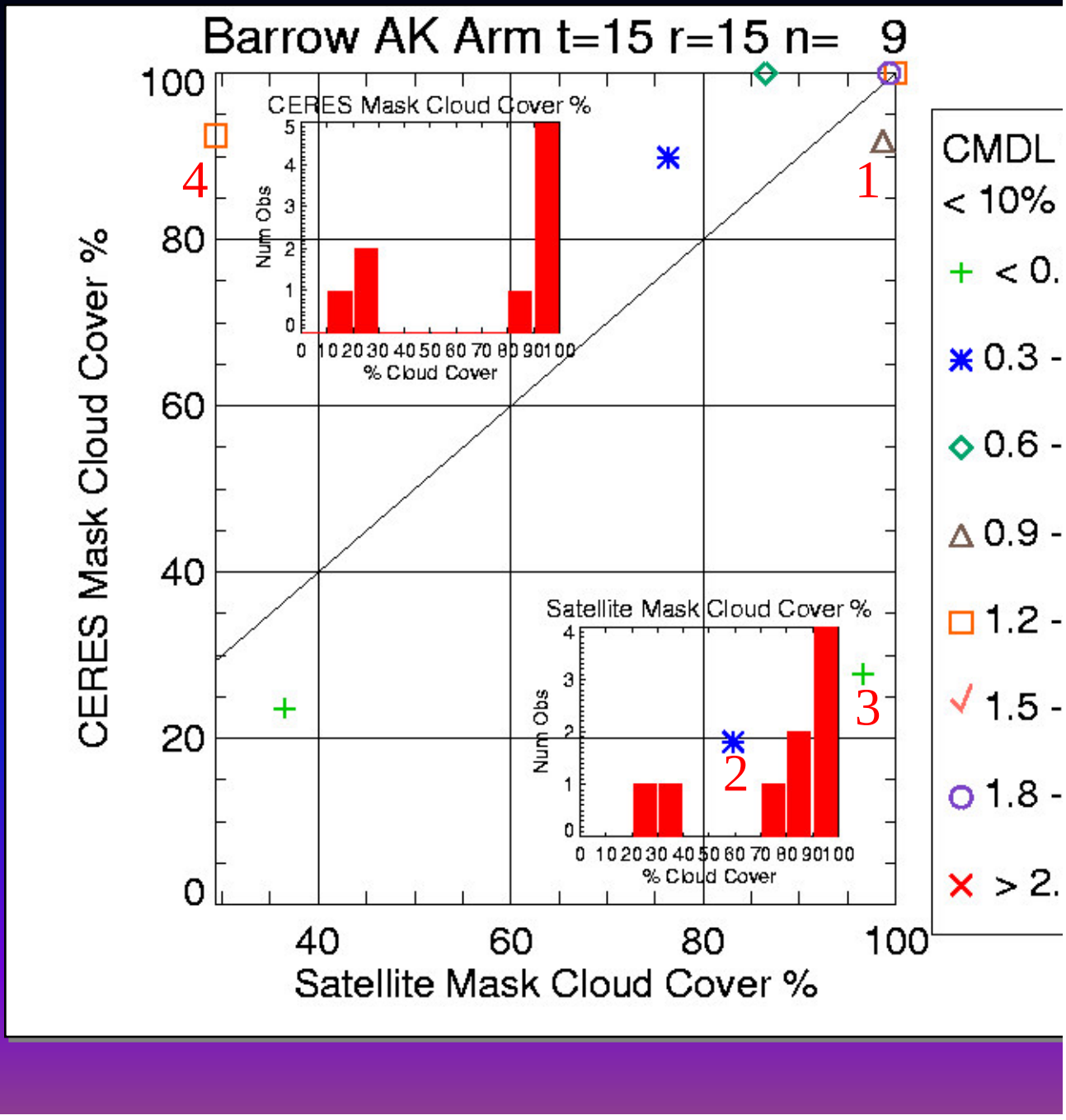
H

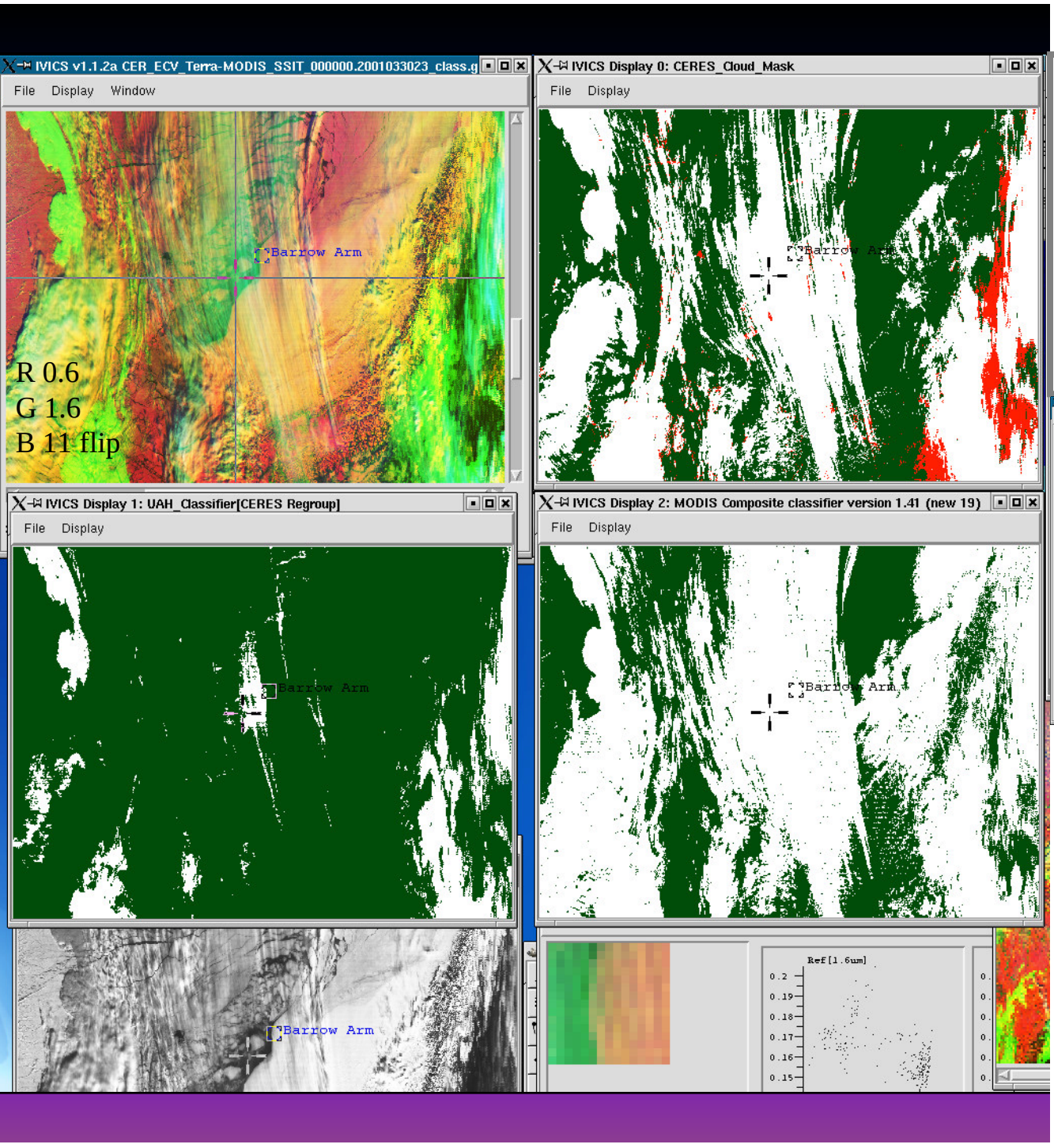




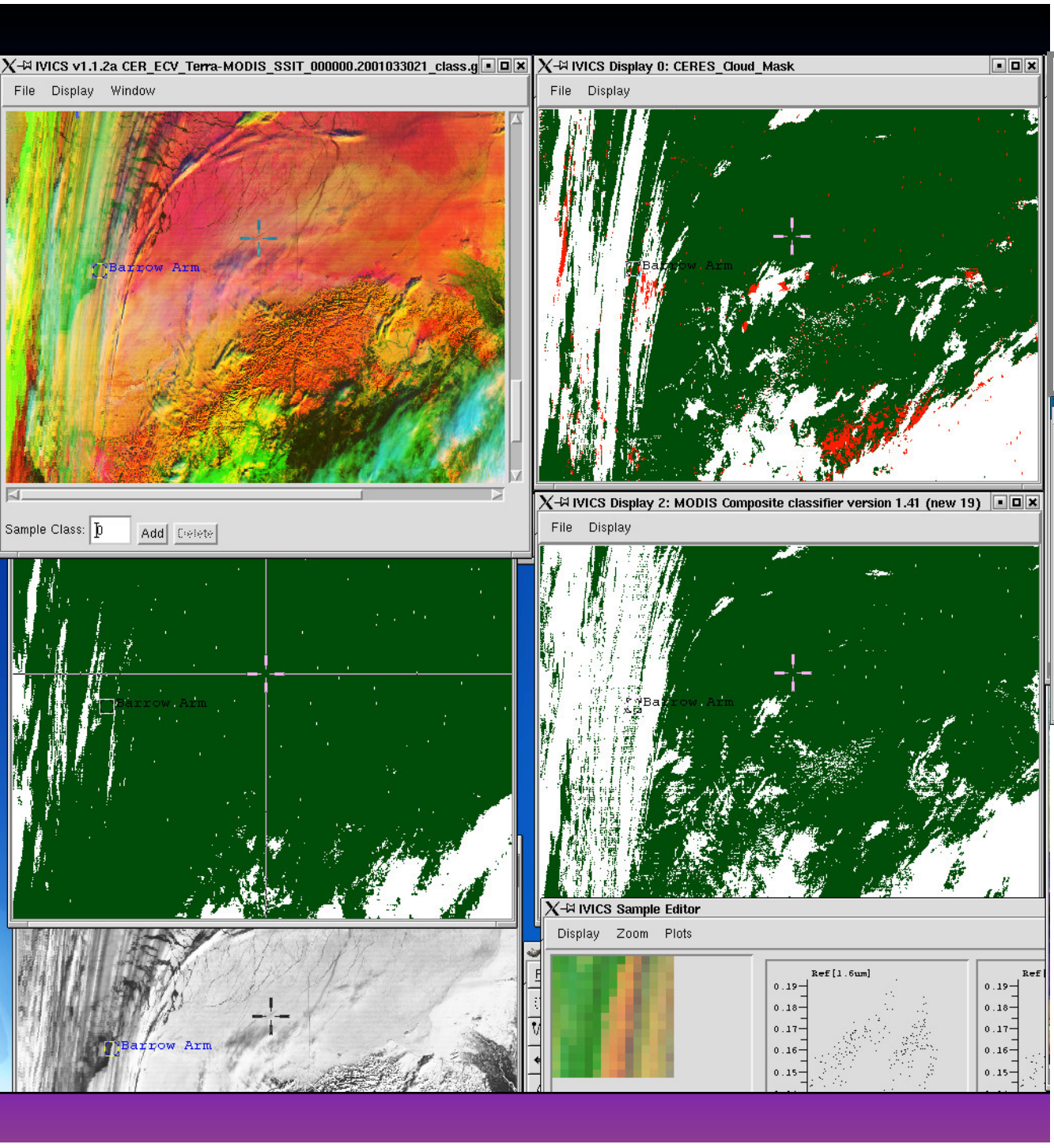




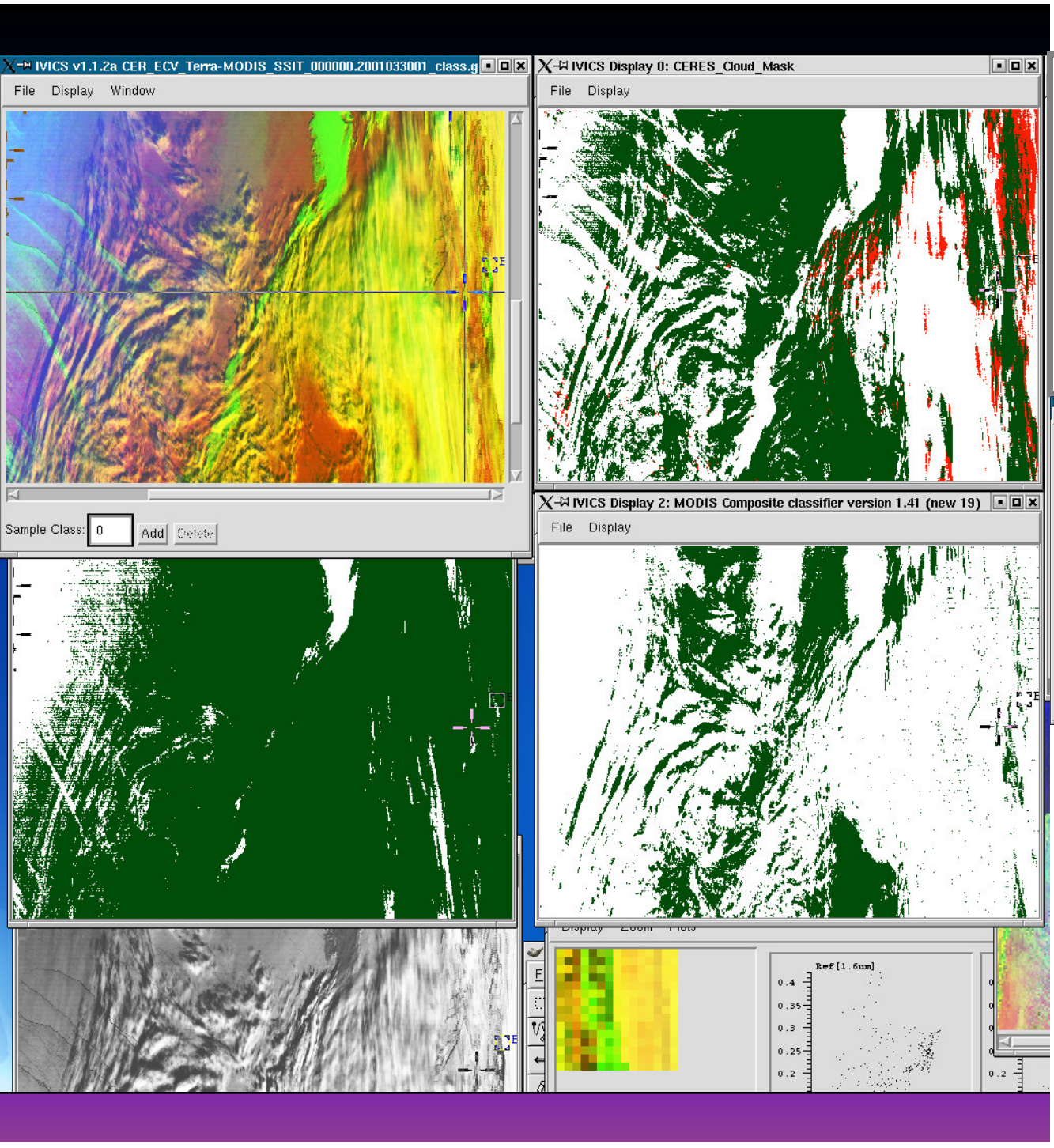

Barrow AK Arm t=15 r=15 n= 9
CERES Mask Cloud Cover %
Satellite Mask Cloud Cover %
CERES Mask Cloud Cover %
Num Obs
% Cloud Cover
Satellite Mask Cloud Cover %
Num Obs
% Cloud Cover
1
2
3
4
CMDL
< 10%
+ < 0.
0.3 -
0.6 -
0.9 -
1.2 -
1.5 -
1.8 -
> 2.



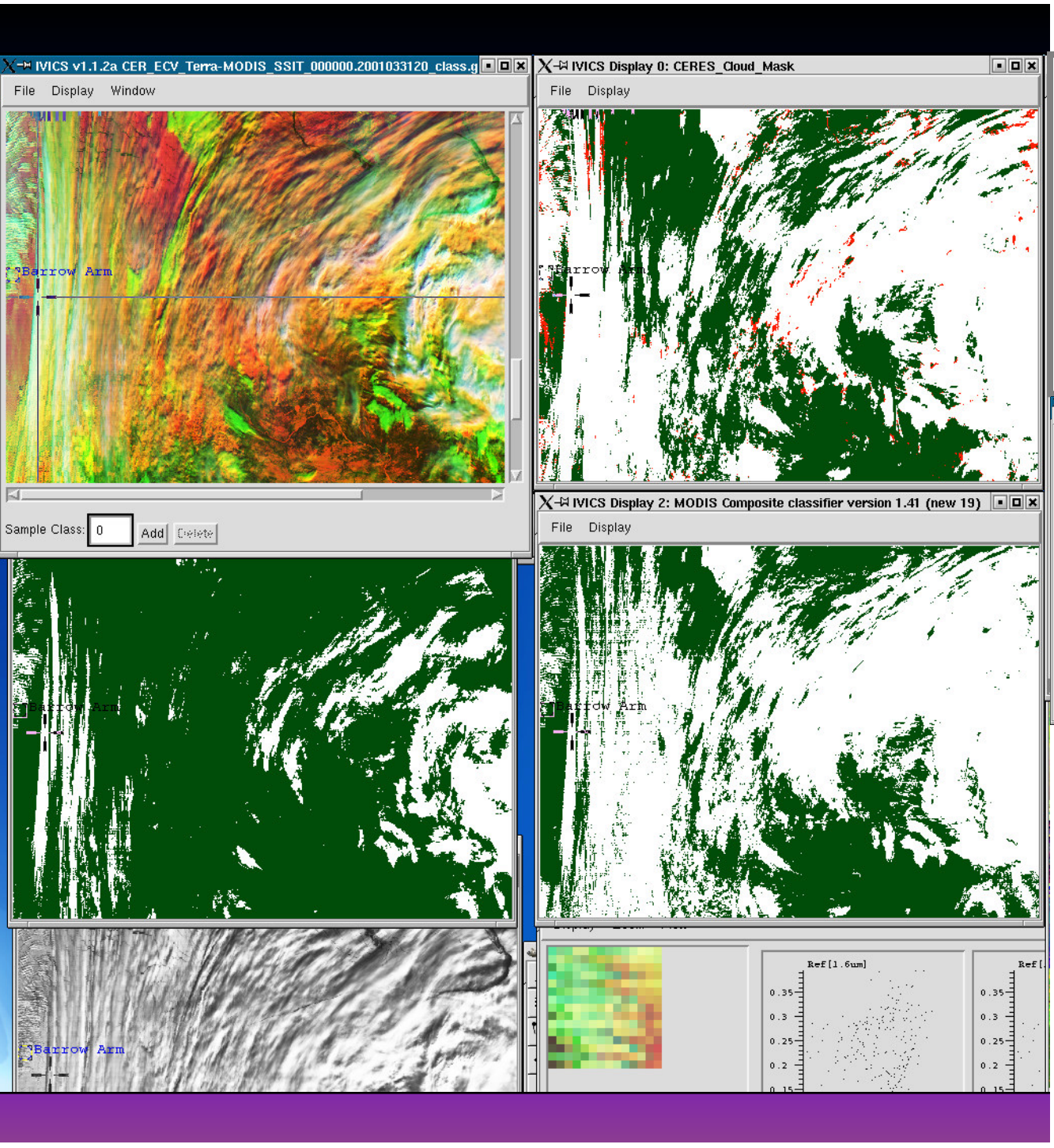
CERES	93
Old UAH	17
New UAH	98
Ceil	100
MPL	100
ARSCL	100
EOD	1.2



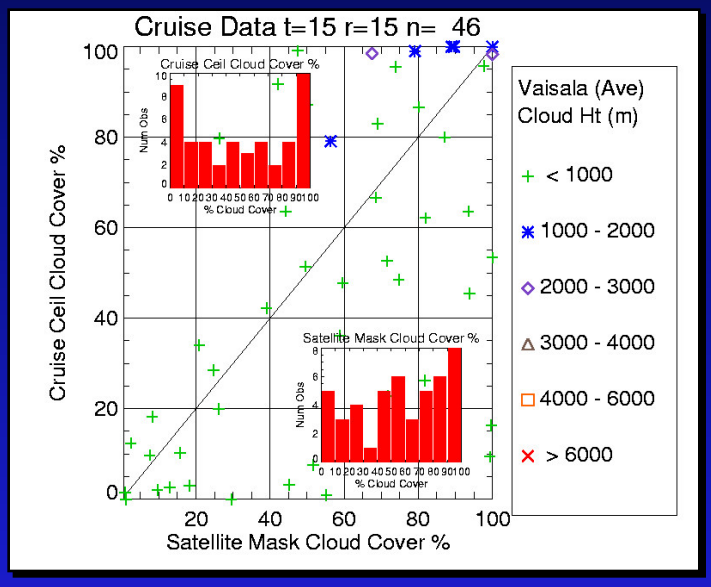
CERES	19
Old UAH	0
New UAH	83
Ceil	96
MPL	100
ARSCL	100
EOD	0.6

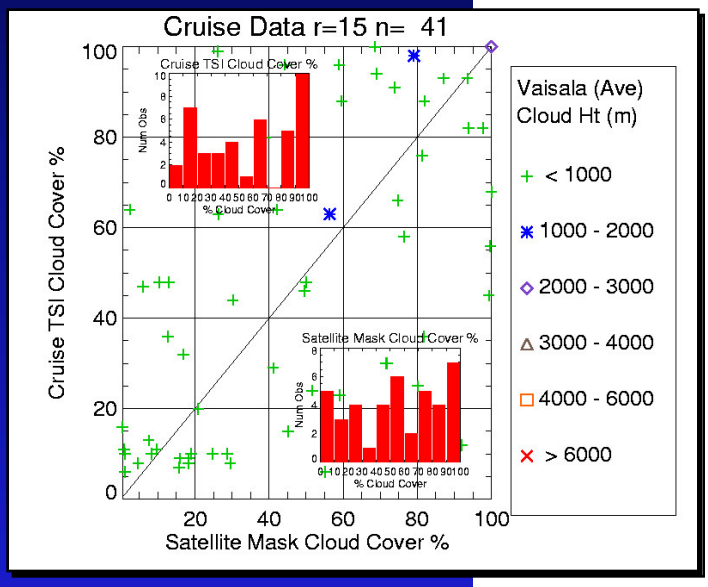


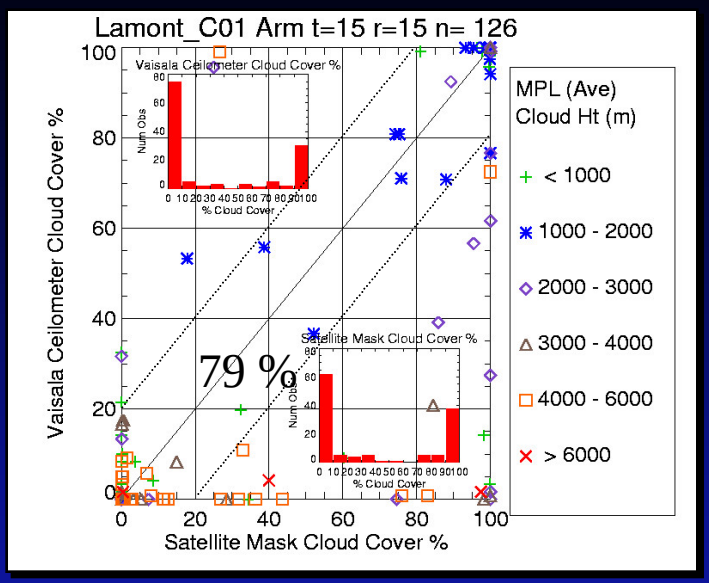
CERES	23
Old UAH	8
New UAH	97
Ceil	4
MPL	92
ARSCL	87
EOD	0.3

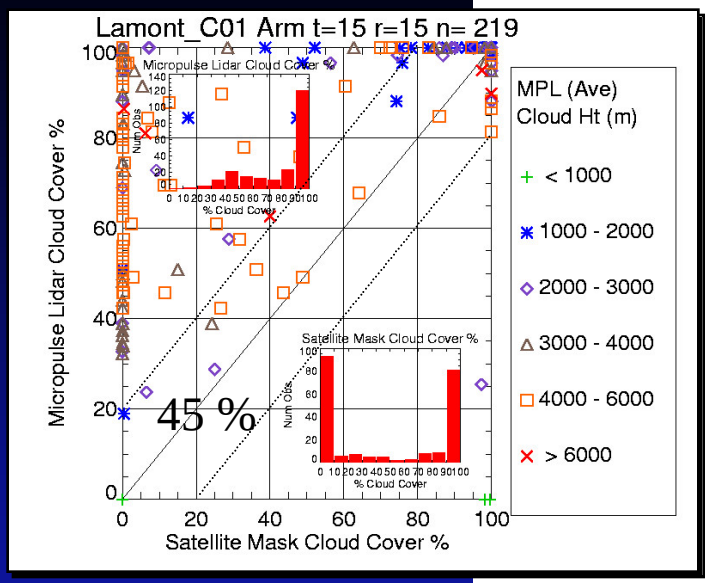


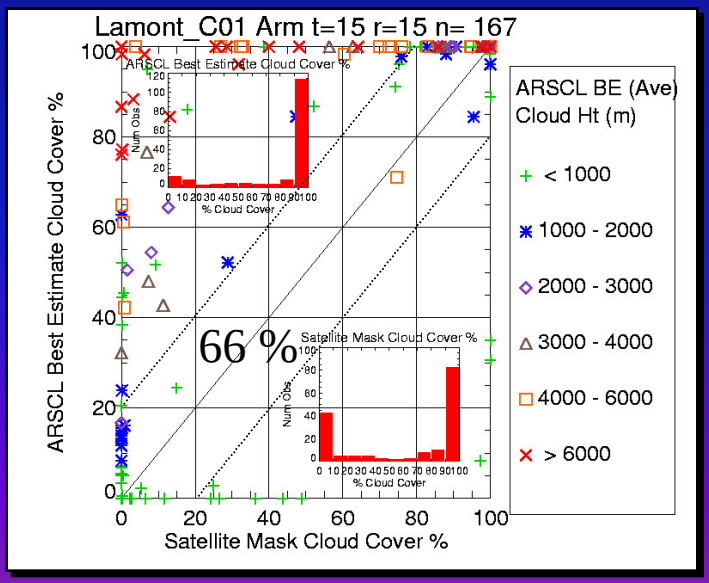
CERES	92
Old UAH	22
New UAH	29
Ceil	100
MPL	98
ARSCL	100
EOD	1.5

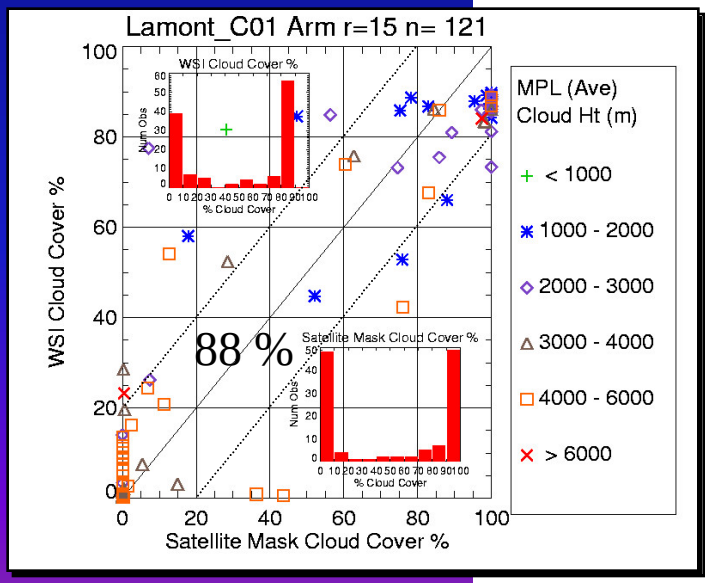

Cruise Data t=15 r=15 n= 46
Cruise Ceil Cloud Cover %
Satellite Mask Cloud Cover %
Num Obs
% Cloud Cover
Vaisala (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000


Cruise Data r=15 n= 41
Cruise TSI Cloud Cover %
Satellite Mask Cloud Cover %
Num Obs
% Cloud Cover
Vaisala (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000


Lamont_C01 Arm t=15 r=15 n= 126
Vaisala Ceilometer Cloud Cover %
Satellite Mask Cloud Cover %
79 %
MPL (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000
Num Obs
% Cloud Cover


Lamont_C01 Arm t=15 r=15 n= 219
Micropulse Lidar Cloud Cover %
Satellite Mask Cloud Cover %
45 %
MPL (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000
Num Obs
% Cloud Cover


Lamont_C01 Arm t=15 r=15 n= 167
ARSCL Best Estimate Cloud Cover %
Satellite Mask Cloud Cover %
66 %
ARSCL BE (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000
Num Obs
% Cloud Cover


Lamont_C01 Arm r=15 n= 121
WSI Cloud Cover %
Satellite Mask Cloud Cover %
88 %
MPL (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000
Num Obs
% Cloud Cover

Problems and Uncertainties

- Surface Instruments generally de
  more cloud than satellite cloud m
  - instrument sensitivity and limitation
  - point sampling over time vs. spatia
- Timing issues and cloud movem
- Thin/high clouds over bright surfa
  (snow/ice) with EOD < ~0.6
- High viewing and solar zenith an

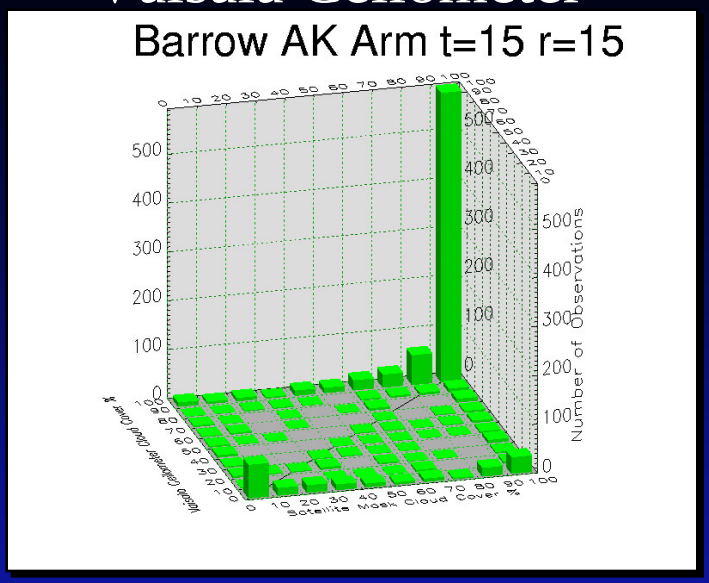
Conclusions

- Cloud masks compare favourabl
- 70-85% agreement with ground
- EOD Analysis determines detect limits of thin cloud ~0.6
- Some surface instruments are m sensitive to thin cloud than mask
- Validation requires multiple instru
- Determine importance of thin clo

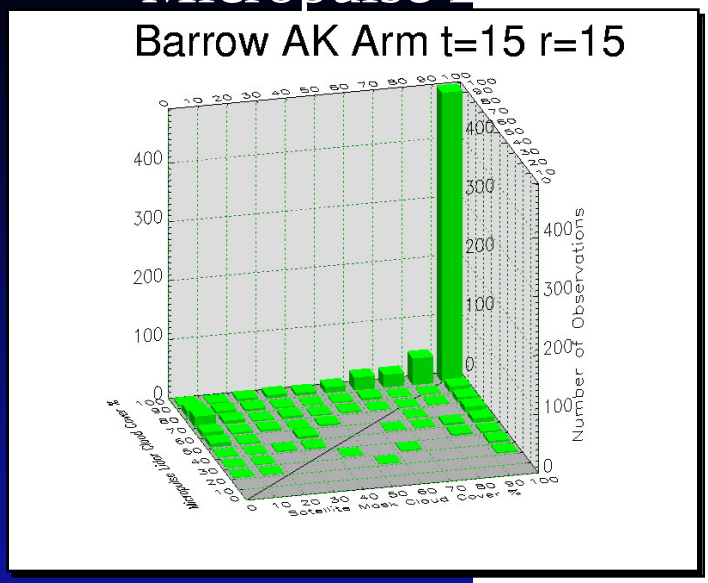
Future Work

- Expand database - sites, instrum
- Journal paper on validation and
  depth analysis is underway
- Refine interpretation of instrume
- Distribute database and code
- Free IVICS visualization softwar
  - http://www.nsstc.uah.edu/ivics

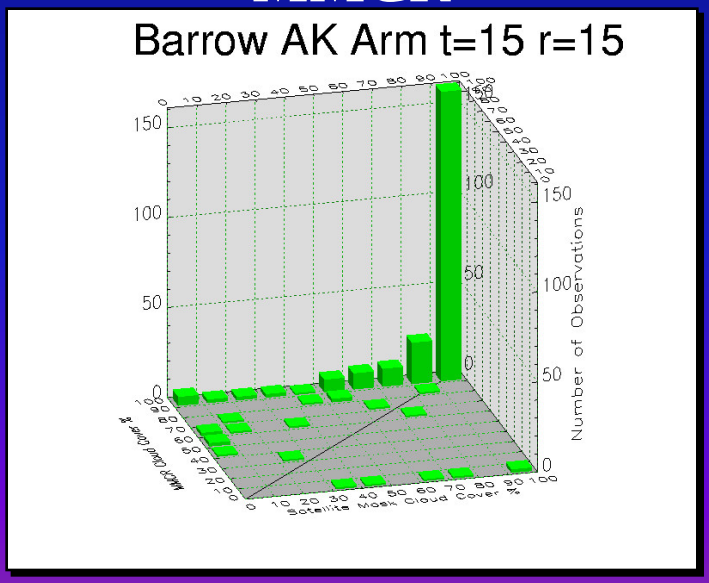
Vaisala Ceilometer



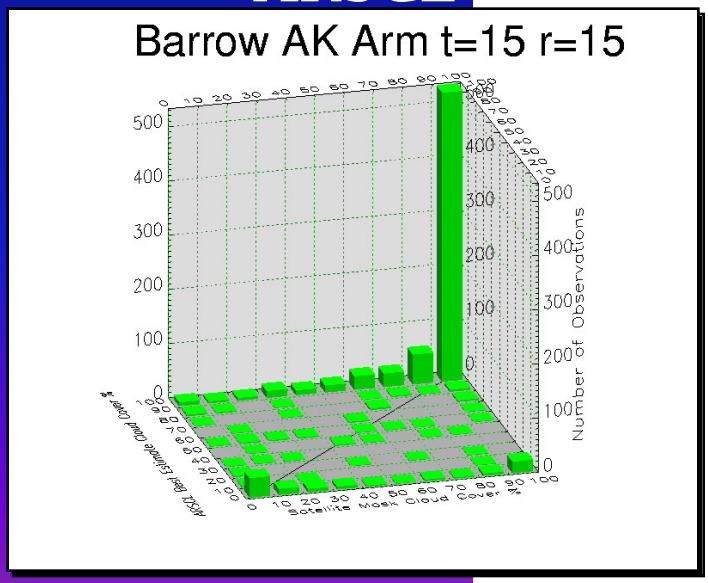
Micropulse L



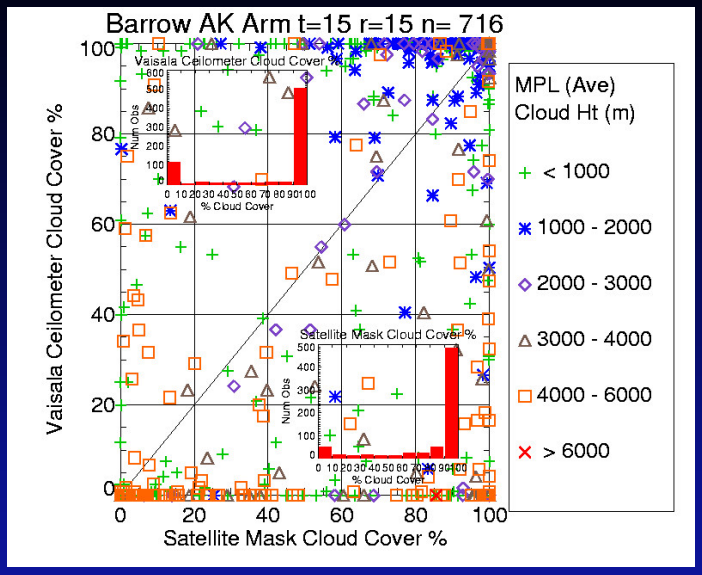
MMCR

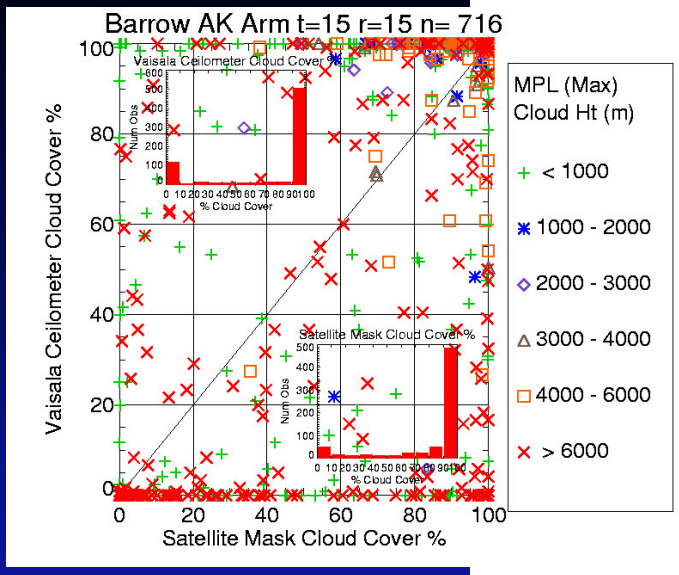


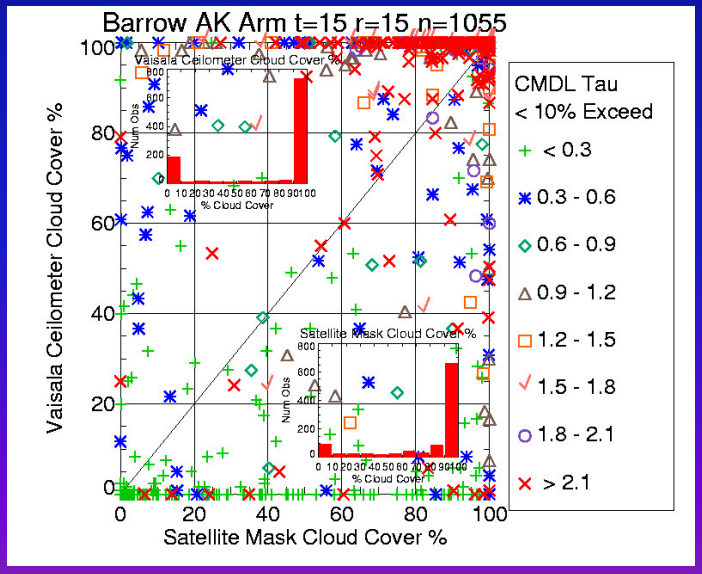
ARSCL

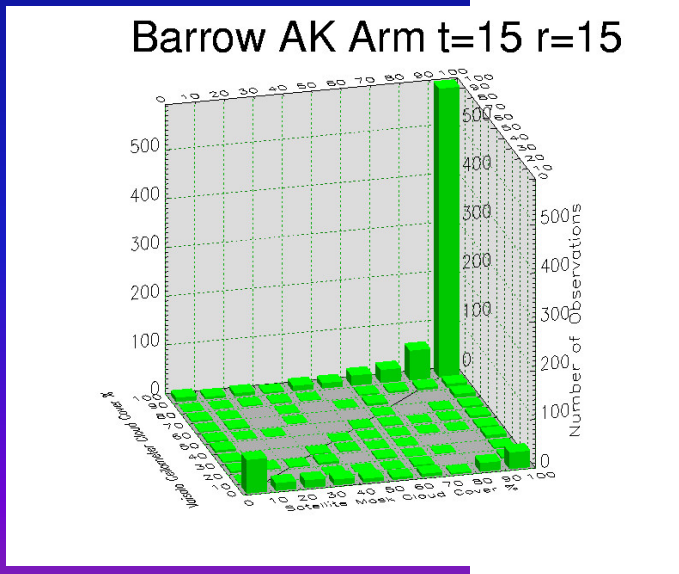


1.4

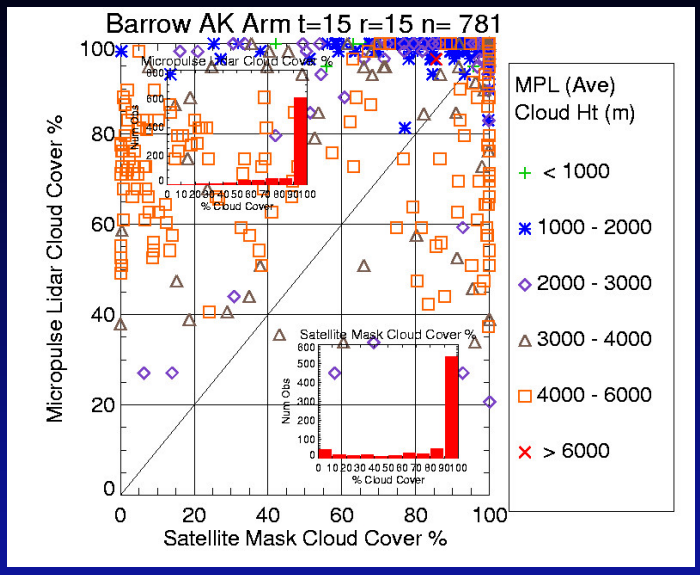

Barrow AK Arm t=15 r=15 n= 716
Vaisala Ceilometer Cloud Cover %
Satellite Mask Cloud Cover %
MPL (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000
Num Obs
% Cloud Cover

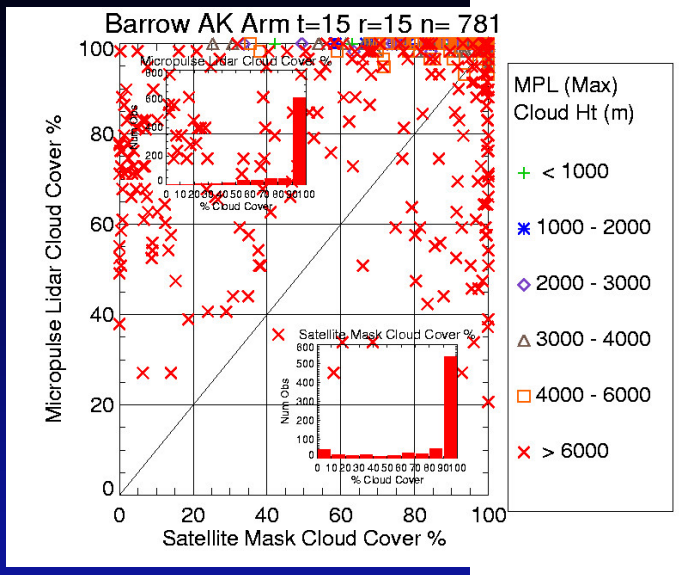

Barrow AK Arm t=15 r=15 n= 716
Vaisala Ceilometer Cloud Cover %
Satellite Mask Cloud Cover %
MPL (Max)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000
Num Obs
% Cloud Cover

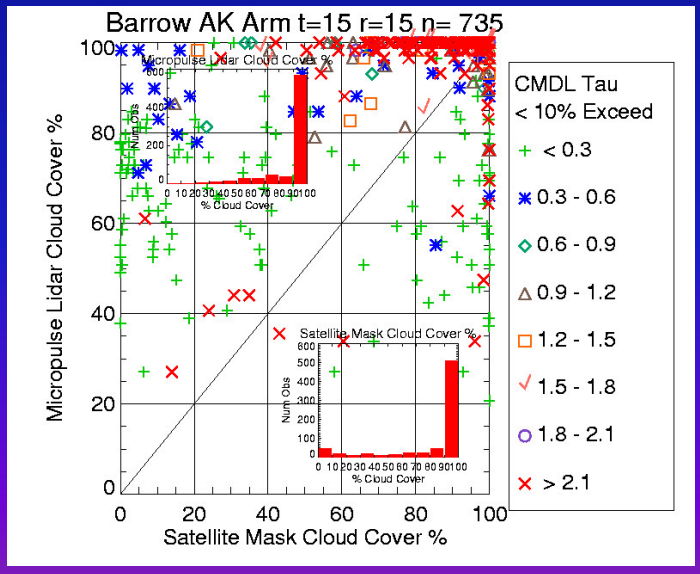

Barrow AK Arm t=15 r=15 n=1055
Vaisala Ceilometer Cloud Cover %
Satellite Mask Cloud Cover %
CMDL Tau
< 10% Exceed
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
1.2 - 1.5
1.5 - 1.8
1.8 - 2.1
> 2.1
Num Obs
% Cloud Cover

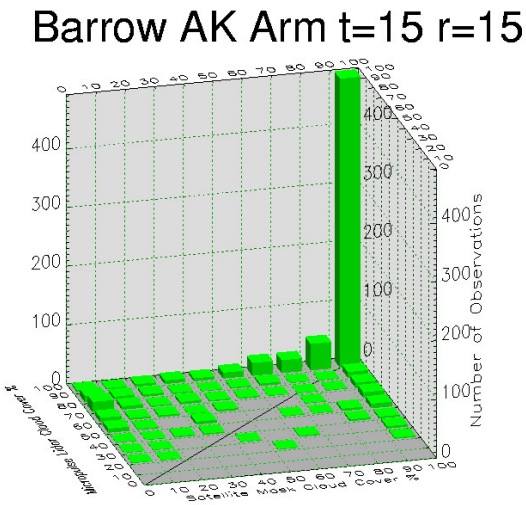

Barrow AK Arm t=15 r=15
Number of Observations

1.4

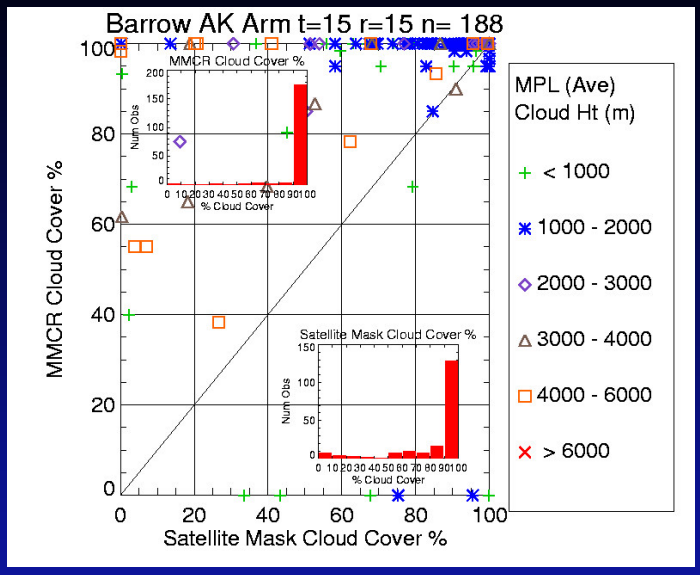

Barrow AK Arm t=15 r=15 n= 781
Micropulse Lidar Cloud Cover %
Satellite Mask Cloud Cover %
MPL (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

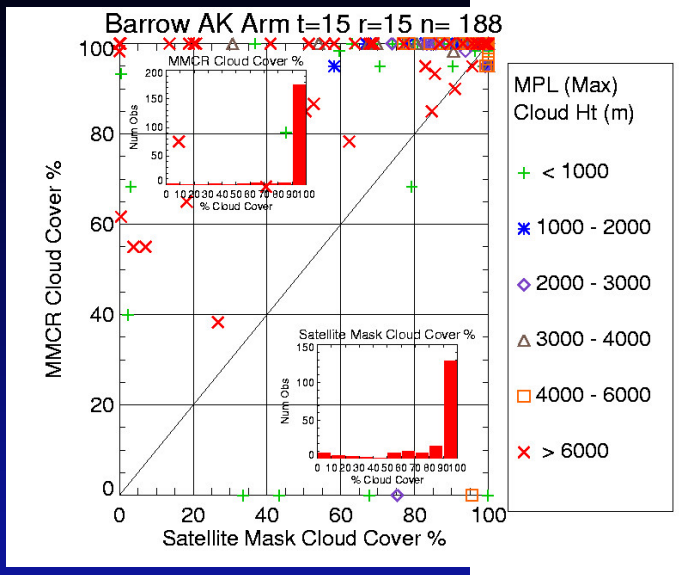

Barrow AK Arm t=15 r=15 n= 781
Micropulse Lidar Cloud Cover %
Satellite Mask Cloud Cover %
MPL (Max)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

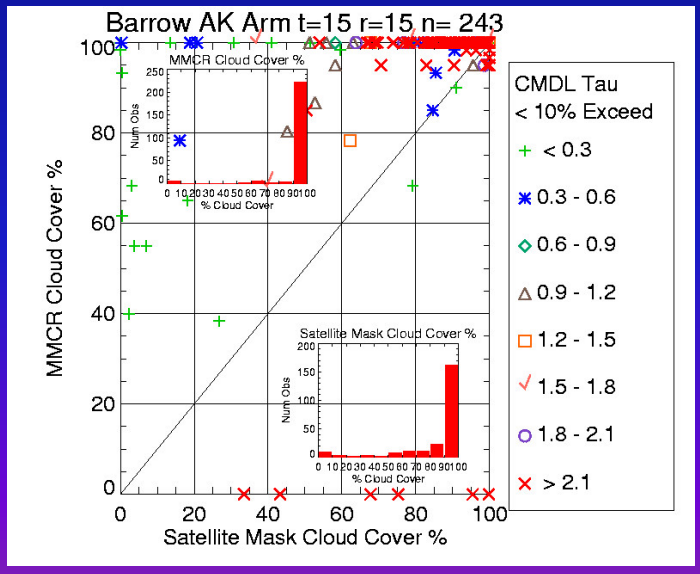

Barrow AK Arm t=15 r=15 n= 735
Micropulse Lidar Cloud Cover %
Satellite Mask Cloud Cover %
CMDL Tau
< 10% Exceed
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
1.2 - 1.5
1.5 - 1.8
1.8 - 2.1
> 2.1

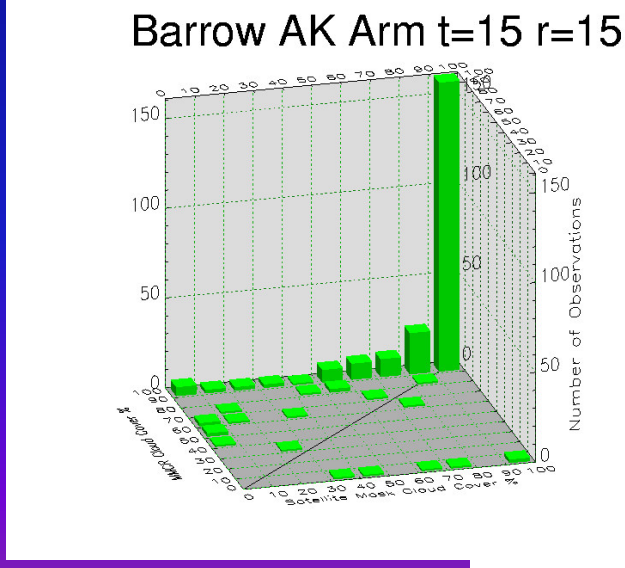

Barrow AK Arm t=15 r=15
Number of Observations

1.4

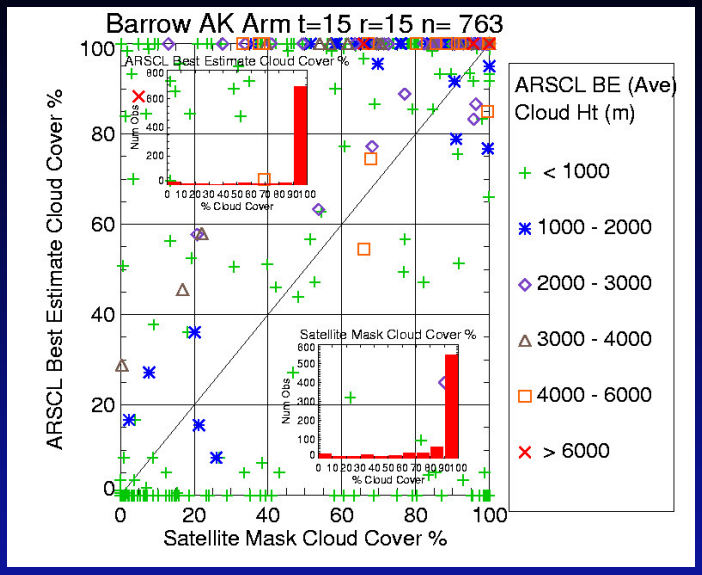

Barrow AK Arm t=15 r=15 n= 188
MMCR Cloud Cover %
Satellite Mask Cloud Cover %
Num Obs
% Cloud Cover
Satellite Mask Cloud Cover %
MPL (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

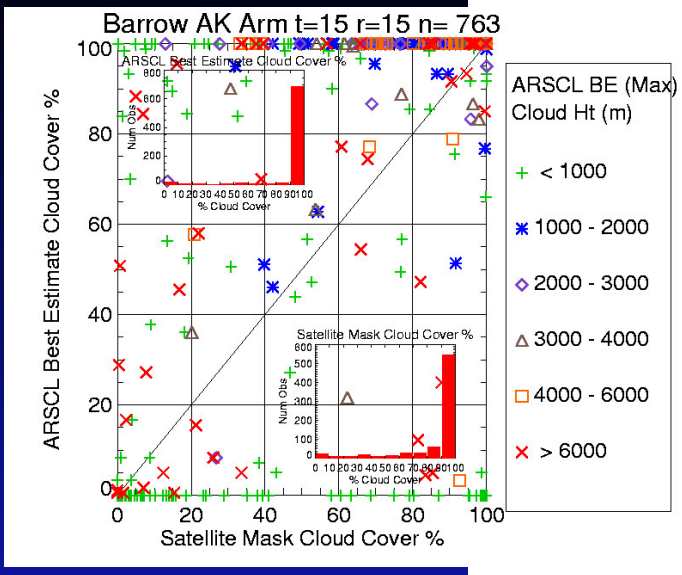

Barrow AK Arm t=15 r=15 n= 188
MMCR Cloud Cover %
Satellite Mask Cloud Cover %
Num Obs
% Cloud Cover
Satellite Mask Cloud Cover %
MPL (Max)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

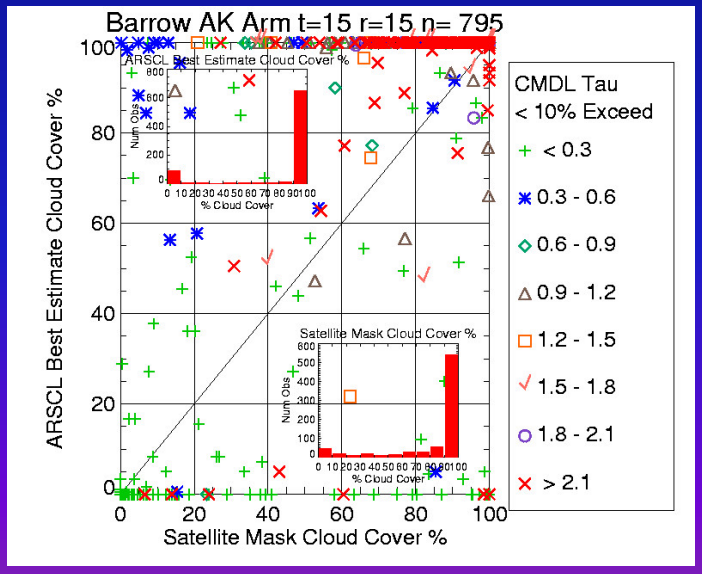

Barrow AK Arm t=15 r=15 n= 243
MMCR Cloud Cover %
Satellite Mask Cloud Cover %
Num Obs
% Cloud Cover
Satellite Mask Cloud Cover %
CMDL Tau
< 10% Exceed
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
1.2 - 1.5
1.5 - 1.8
1.8 - 2.1
> 2.1

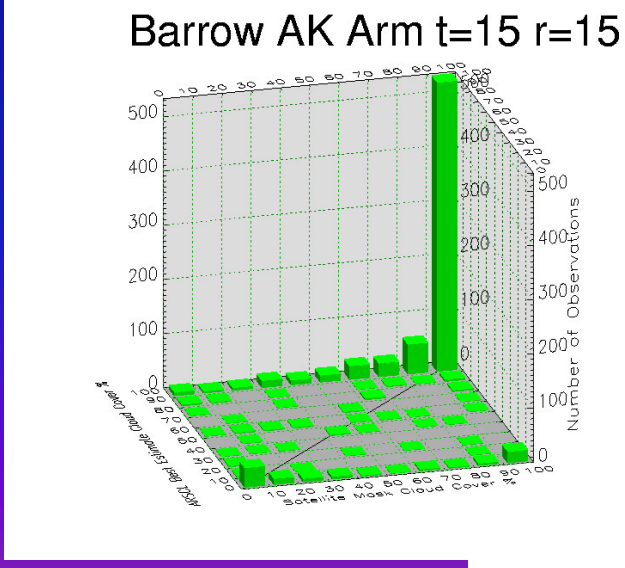

Barrow AK Arm t=15 r=15
Number of Observations

1.4

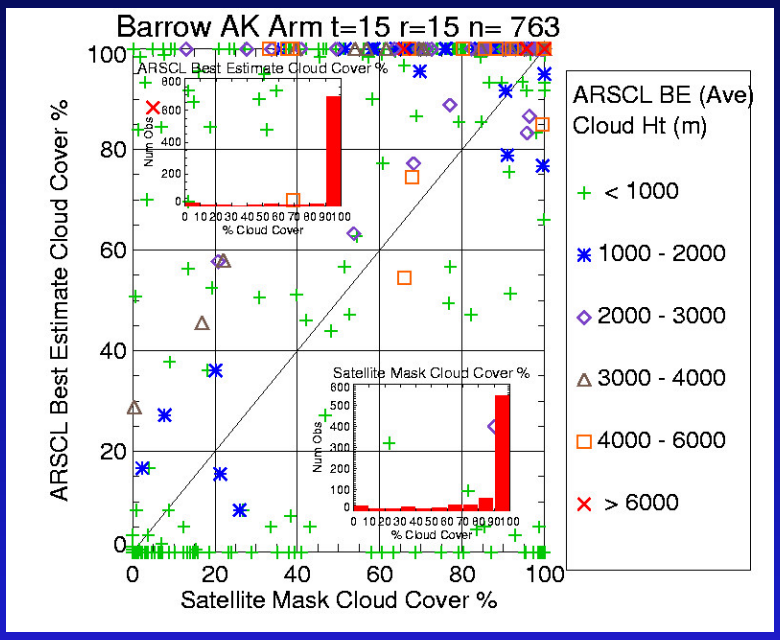
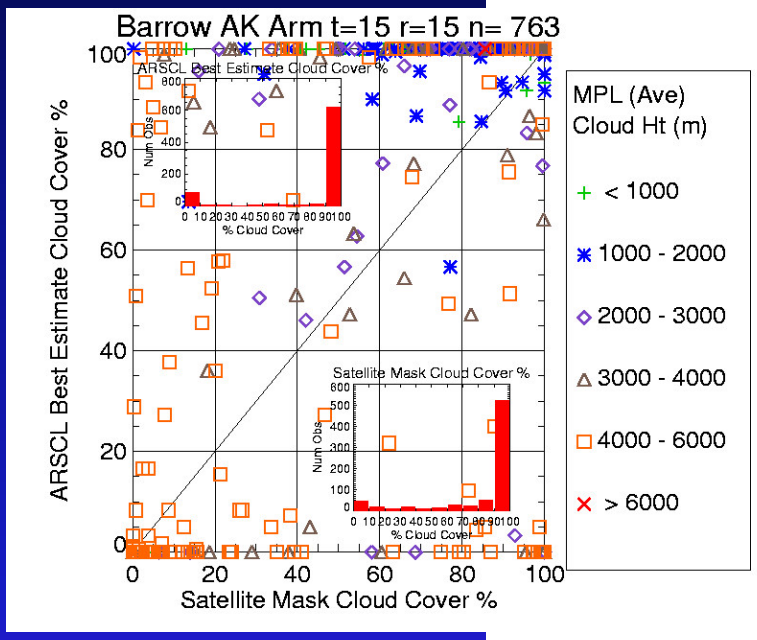

Barrow AK Arm t=15 r=15 n= 763
ARSCL Best Estimate Cloud Cover %
Satellite Mask Cloud Cover %
ARSCL BE (Ave)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000
Num Obs
% Cloud Cover


Barrow AK Arm t=15 r=15 n= 763
ARSCL Best Estimate Cloud Cover %
Satellite Mask Cloud Cover %
ARSCL BE (Max)
Cloud Ht (m)
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000
Num Obs
% Cloud Cover


Barrow AK Arm t=15 r=15 n= 795
ARSCL Best Estimate Cloud Cover %
Satellite Mask Cloud Cover %
CMDL Tau
< 10% Exceed
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
1.2 - 1.5
1.5 - 1.8
1.8 - 2.1
> 2.1
Num Obs
% Cloud Cover


Barrow AK Arm t=15 r=15
Number of Observations

ARSCL Height



MPL Heig