Enhanced Cloud Algorithm From Collocated CALIPSO, CloudSat and MODIS

Sunny Sun-Mack[1], Patrick Minnis[2], Yuhong Yi[1], Yan Chen[1], Sharon Gibson[1]
Qing Trepte[1], Pat Heck[3], Seiji Kato[2], Bruce Wielicki[2] (PI)

(1) SSAI, Hampton, VA, USA
(2) NASA Langley Research Center, Hampton, VA, USA
(3) CIMSS, Wisconsin, USA

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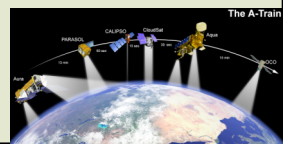


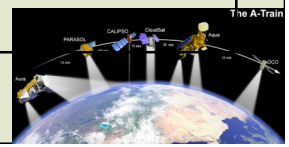
Objectives

- **Develop an integrated data set to provide global vertical profiles of aerosols, clouds, and broadband radiative fluxes using combined NASA A-Train data from**

  - ***Aqua*** **CERES (broadband fluxes constrain RTM calcs)**
  - **MODIS aerosols (MOD04)**
  - **CERES-MODIS cloud properties (from CERES algorithms)**
  - **CALIPSO lidar aerosol and cloud data**
  - **CloudSat CPR cloud data**

- **Use CALIPSO and CloudSat data products to**

  - **Develop improved algorithms for CERES-MODIS Ed3 clouds, and future NPP cloud algorithm.**



CERES-MODIS Cloud Retrieval Methodology

(Apply CERES algorithms to MODIS imager data)

Compute ice & water phase solution, select most likely phase based on temperature, model fits, LBTM classification, 2.1-μm reflectance

DAY: VISST (Visible Infrared Solar-Infrared Split-Window Technique)

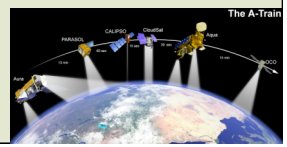
0.65, 3.8, 10.8, & 12.0 μm *see Minnis et al. (1995, 1998, 2007b)*

NIGHT: SIST (Solar-infrared Infrared Split-Window Technique)

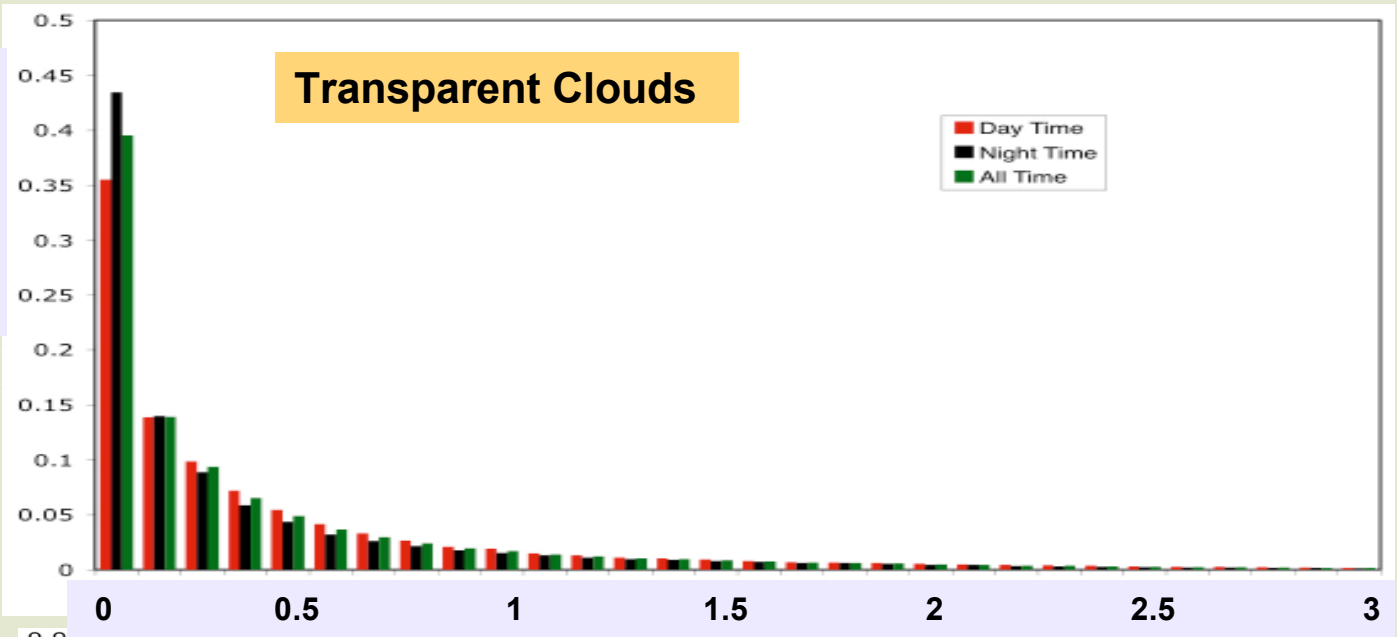
3.8, 10.8, & 12.0 μm *see Minnis et al. (1995, 1998, 2007b)*

SNOW (DAY): SINT (Solar-Infrared Infrared Near-Infrared Technique)

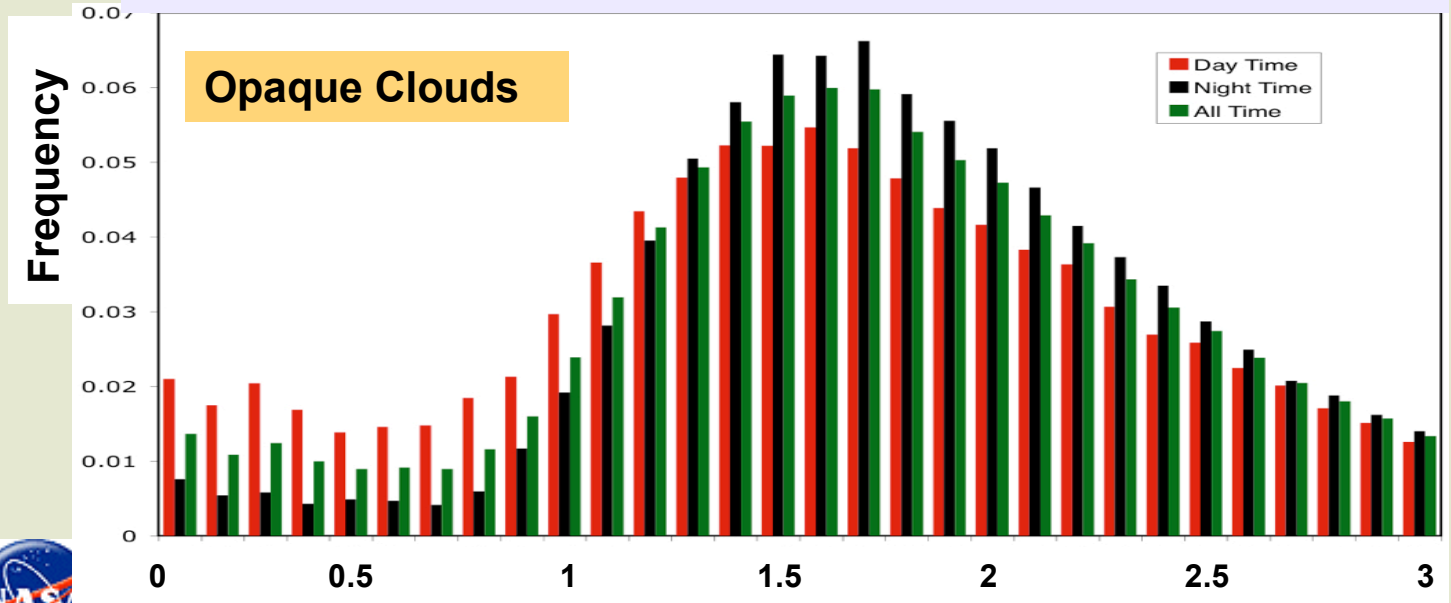
2.1, 3.8, 10.8, & 12.0 μm *see Platnick (JGR, 2001), Minnis et al. (2007b)*



CALIPSO Optical Depth Histogram (Single Ice Layer) for July 2006

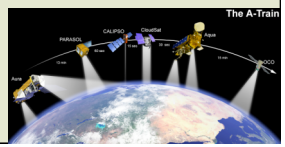


CALIPSO Extinction QC Flag=0 & 1



CALIPSO Extinction QC Flag=16 & 17

CALIPSO Optical Depth

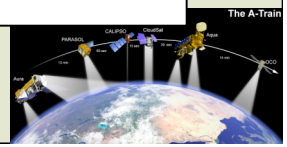


Enhanced Cloud Retrieval Along A-Train Track

For single layer and transparent CALIPSO clouds:

- **If CALIPSO optical depth > 4, no Tcld adjustment**
- **If CALIPSO optical depth < 4, and if CERES-MODIS cloud is outside of CALIPSO cloud top and base**

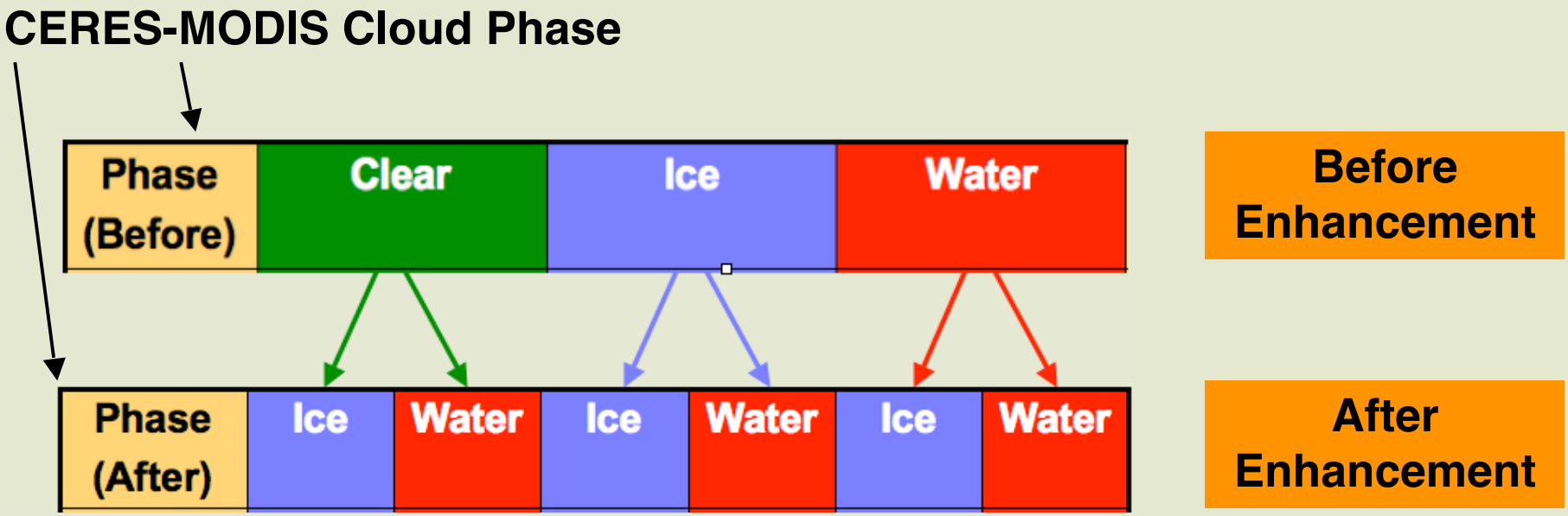
Then adjust CERES-MODIS cloud temperature to CALIPSO value, redo some of the streamlined VISST / SINT/ SIST to try to retrieve the rest of cloud properties (tau, size….)

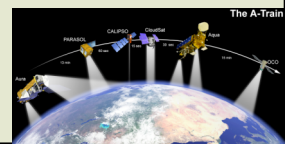


Possible CERES-MODIS Cloud Phase Changes

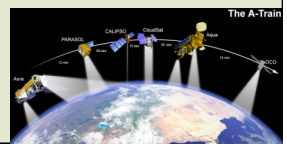
(Before and After the Enhancement)

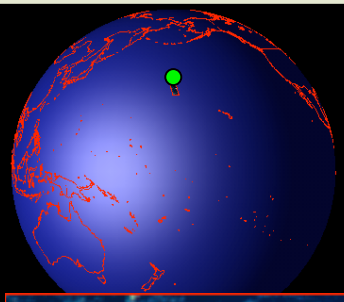
For single transparent calipso clouds:





Before and After Cases



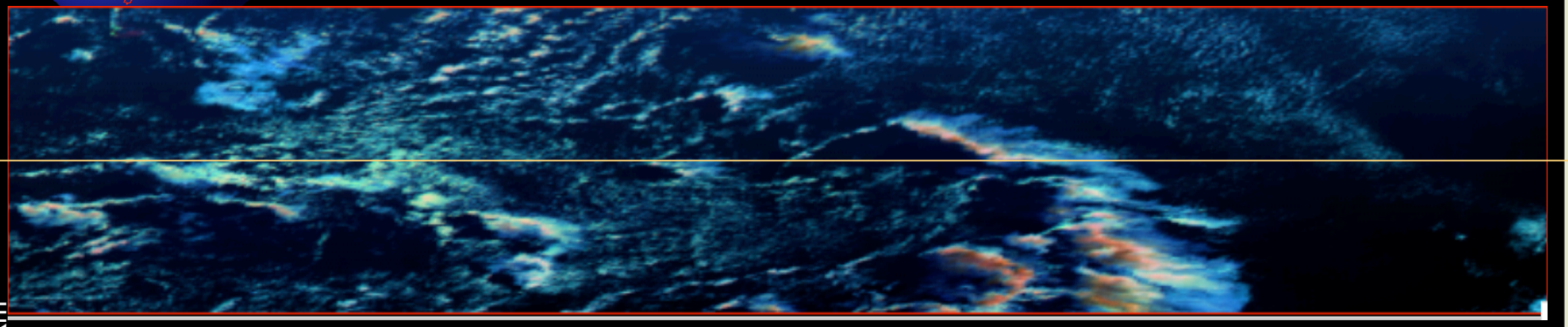


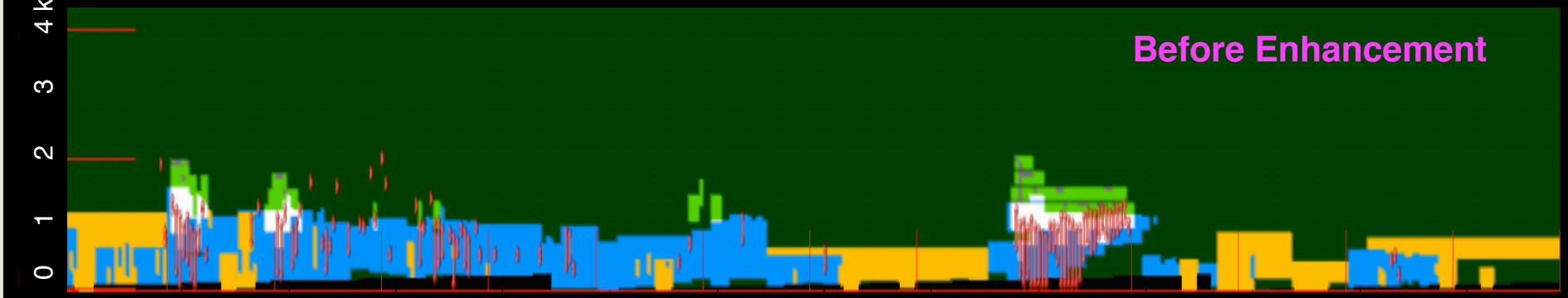
July 15, 2006, Hour 01
Day Time

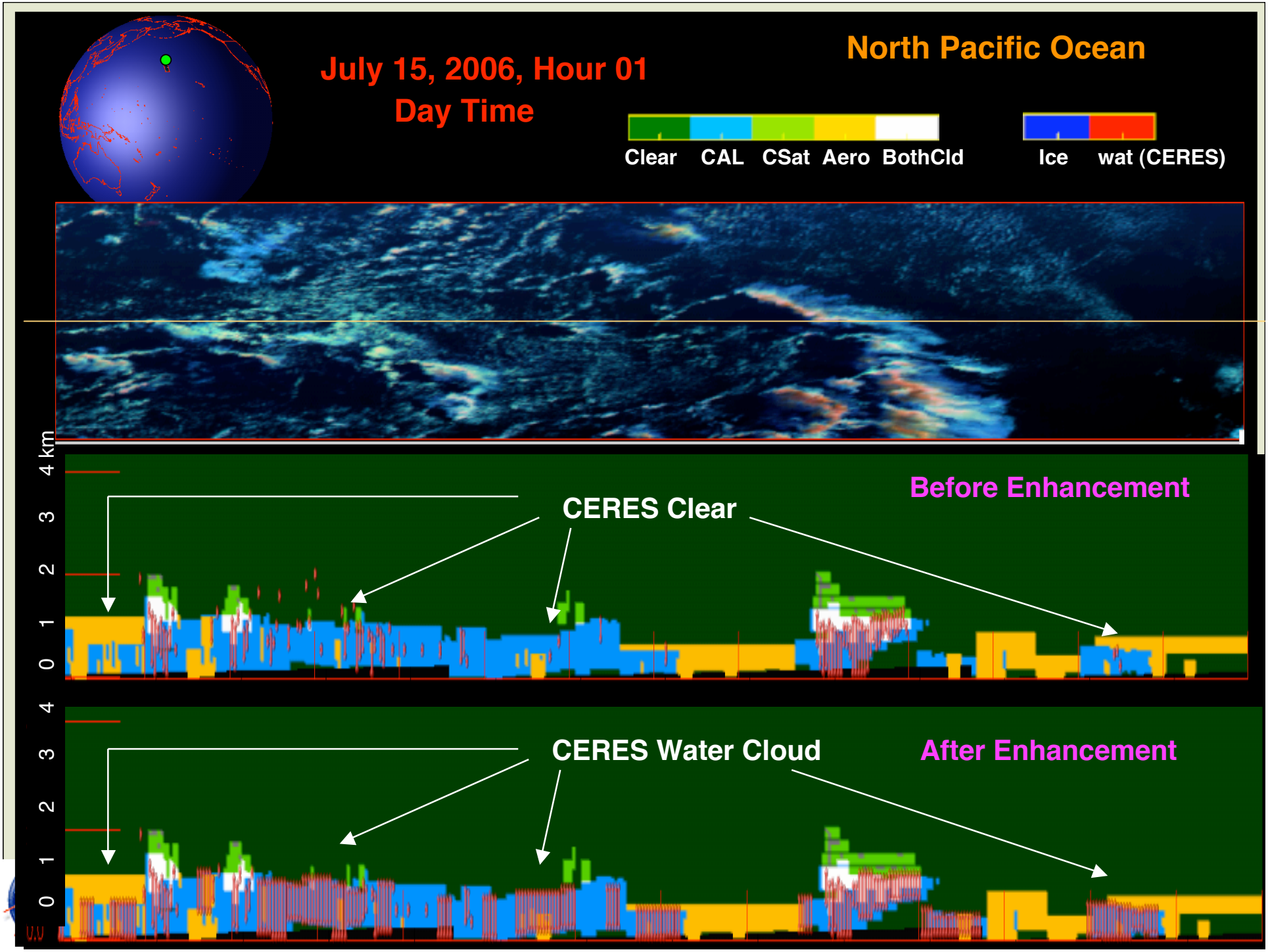
North Pacific Ocean

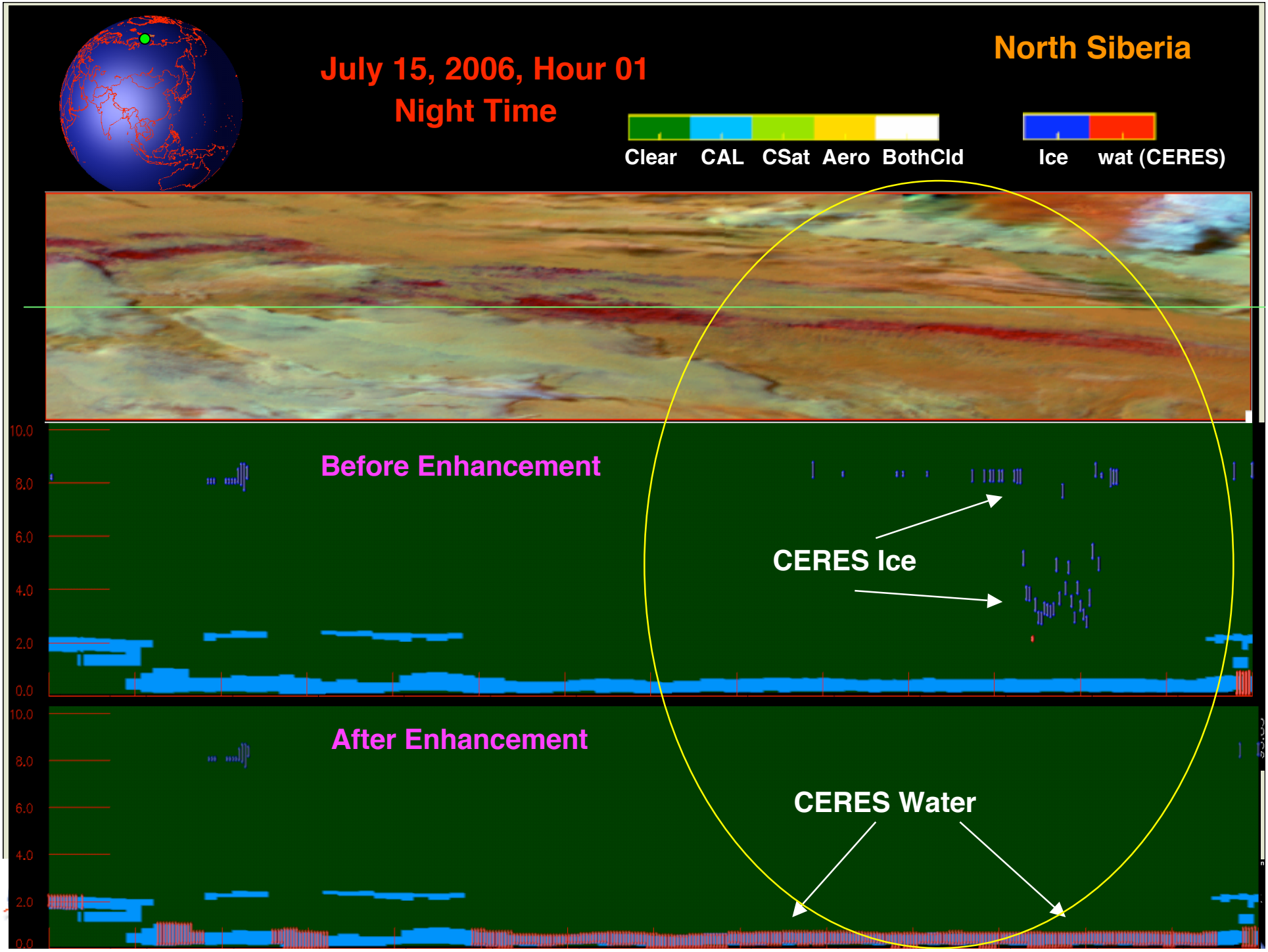
Clear CAL CSat Aero BothCld

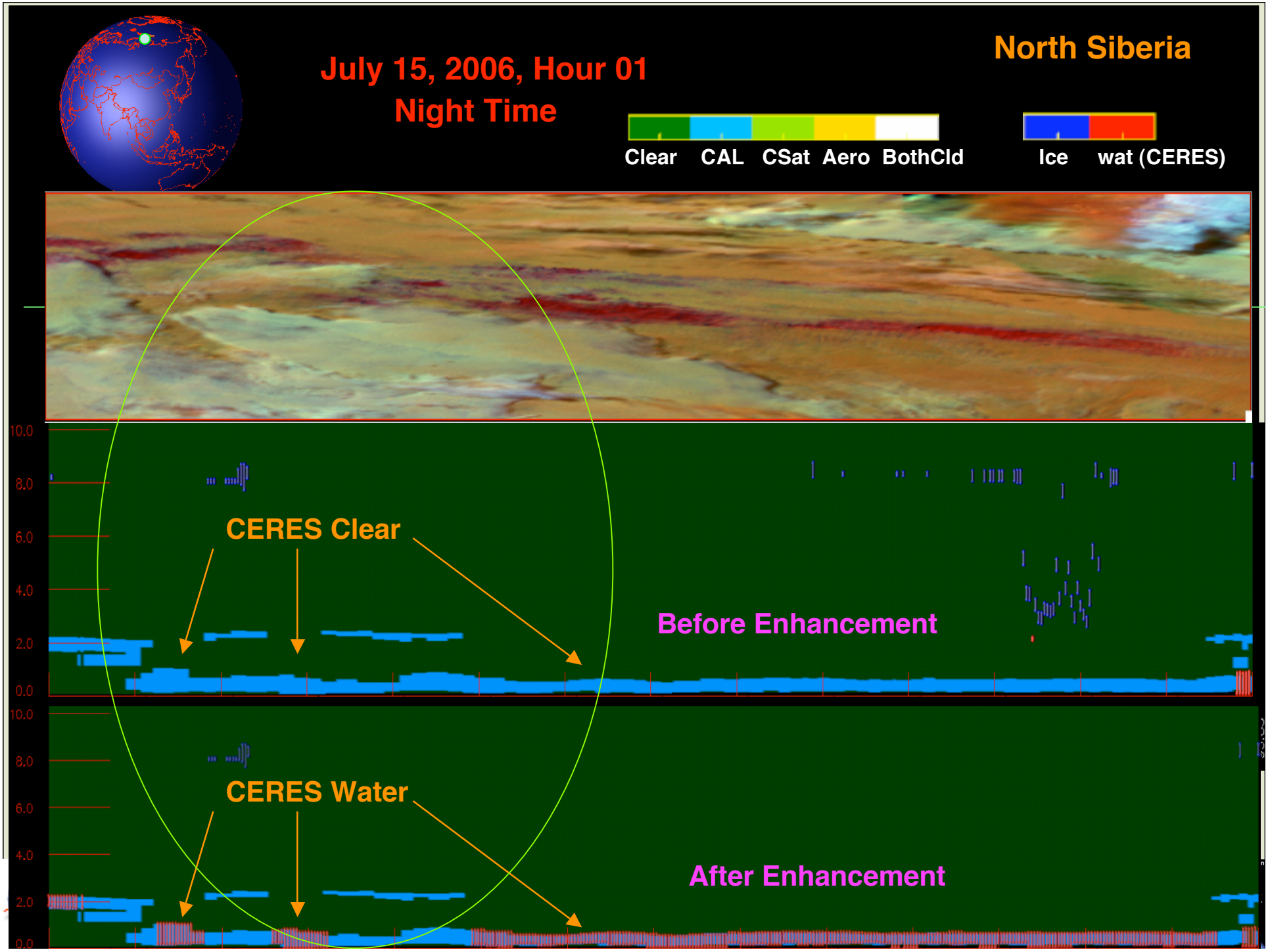
Ice wat (CERES)

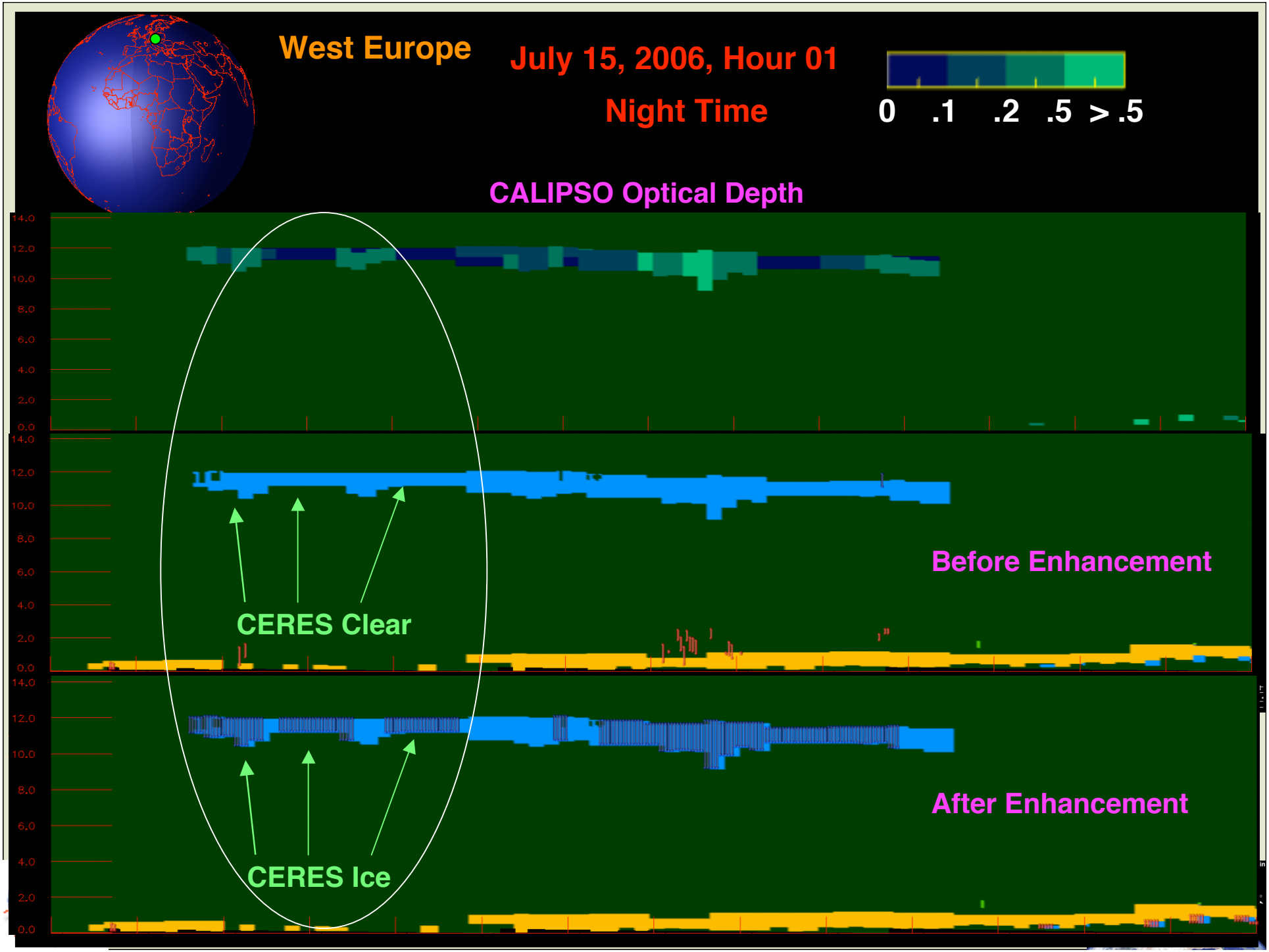


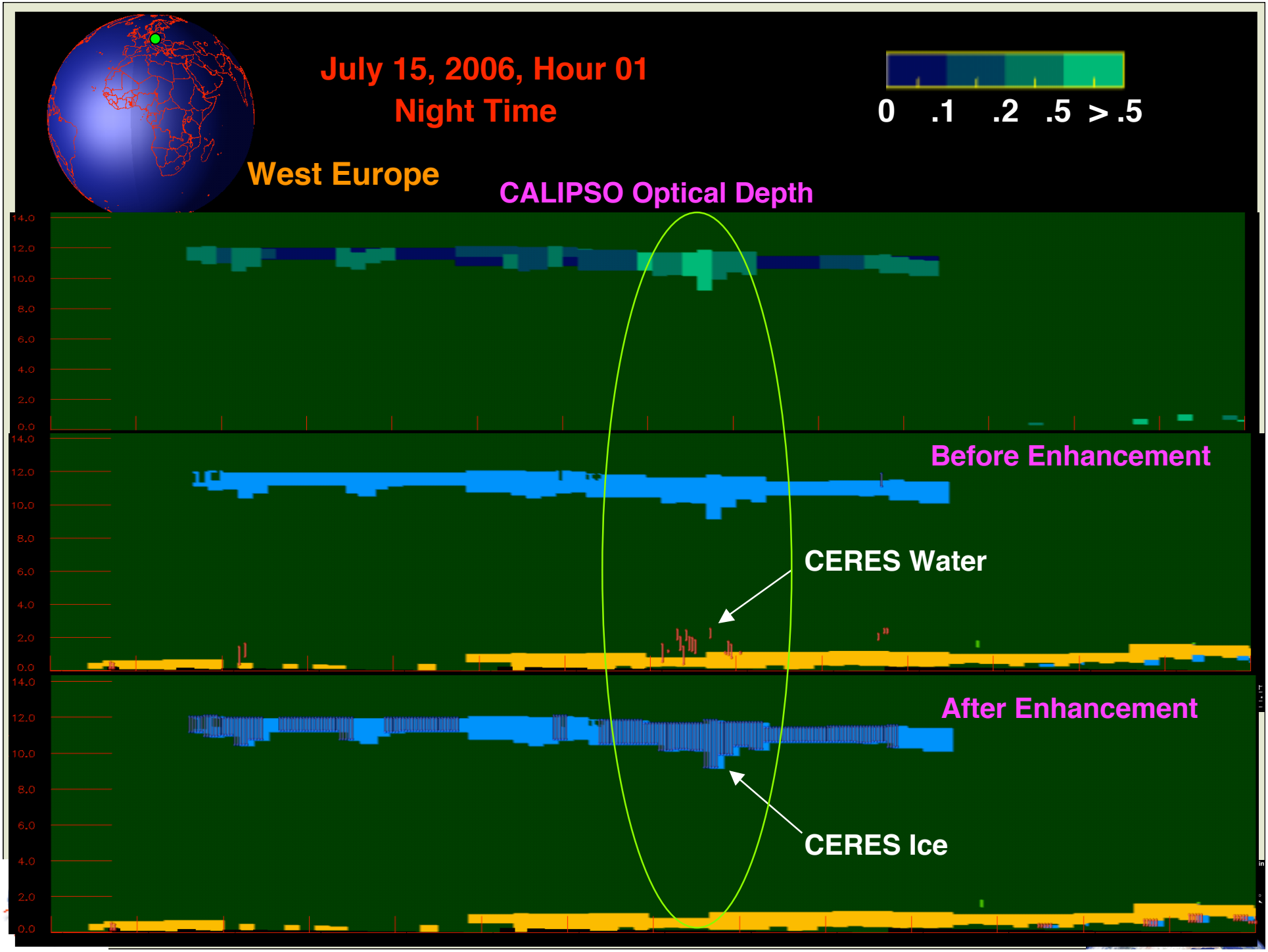


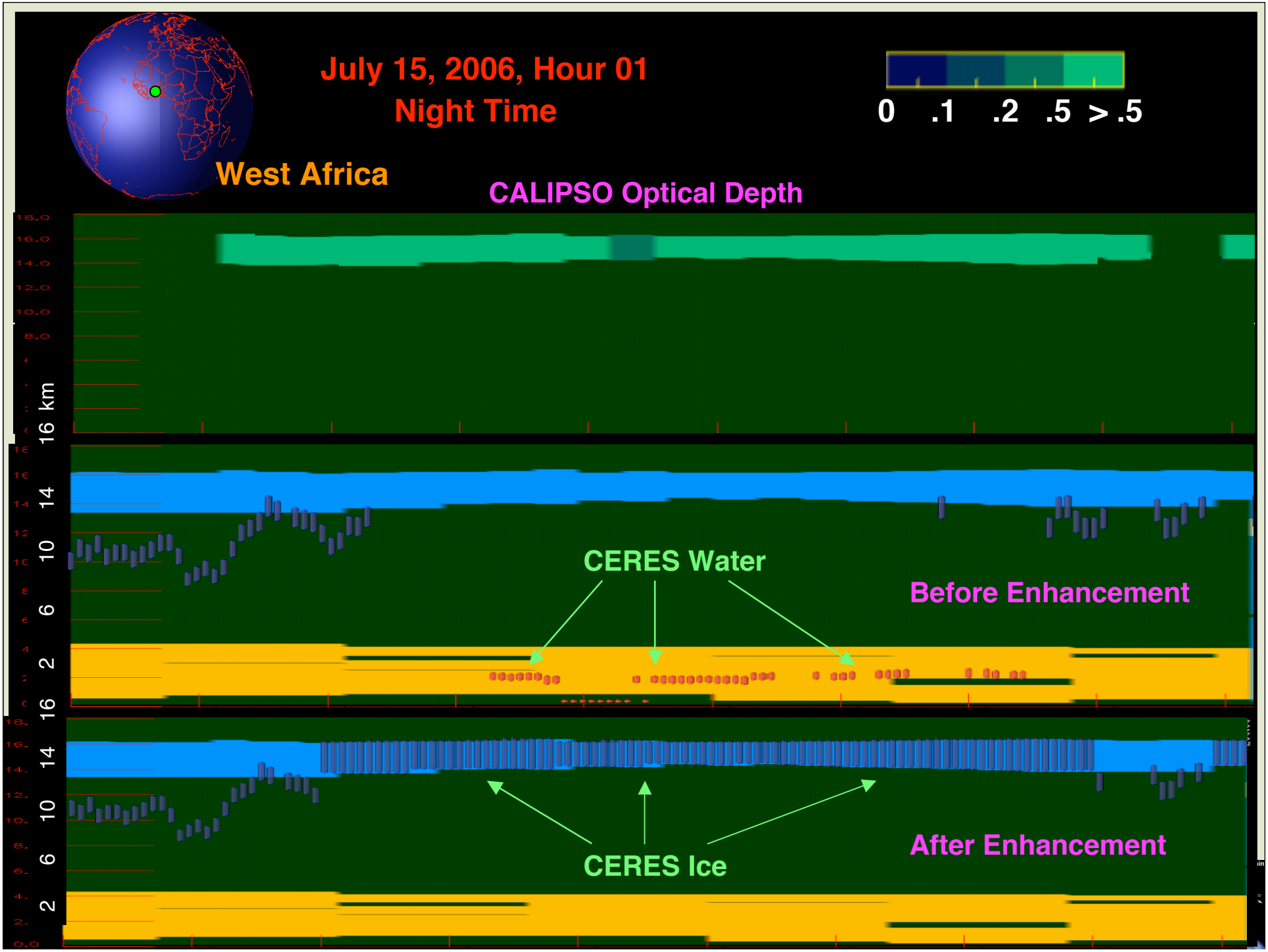

July 15, 2006, Hour 01
Day Time
North Pacific Ocean
Clear
CAL
CSat
Aero
BothCld
Ice
wat (CERES)
4 km
3
2
1
0
CERES Clear
Before Enhancement
4
3
2
1
0
CERES Water Cloud
After Enhancement


July 15, 2006, Hour 01
Night Time
North Siberia
Clear
CAL
CSat
Aero
BothCld
Ice
wat (CERES)
Before Enhancement
CERES Ice
After Enhancement
CERES Water
10.0
8.0
6.0
4.0
2.0
0.0


July 15, 2006, Hour 01
Night Time
North Siberia
Clear CAL CSat Aero BothCld
Ice wat (CERES)
CERES Clear
Before Enhancement
CERES Water
After Enhancement
10.0
8.0
6.0
4.0
2.0
0.0


West Europe
July 15, 2006, Hour 01
Night Time
0 .1 .2 .5 > .5
CALIPSO Optical Depth
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Before Enhancement
CERES Clear
After Enhancement
CERES Ice


July 15, 2006, Hour 01
Night Time
West Europe
0 .1 .2 .5 > .5
CALIPSO Optical Depth
Before Enhancement
CERES Water
After Enhancement
CERES Ice
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0


July 15, 2006, Hour 01
Night Time
0 .1 .2 .5 > .5
West Africa
CALIPSO Optical Depth
18.0
16.0
14.0
12.0
10.0
8.0
km
16
14
10
6
2
CERES Water
Before Enhancement
CERES Ice
After Enhancement

3 Days of Merged CALIPSO, CloudSat and MODIS
July 2006, day 08, 15, and 22

(1) Non-Polar Region

(2) CALIPSO: Single and Transparent Layer

(3) CALIPSO: Optical Depth < 4

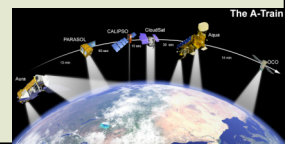
→ 131, 385 pixels

Before Enhancement

CERES (Before)	Clear	Ice	Water	NoRet	Bad Data
%	71.42 (%)	10.5 (%)	15.59 (%)	2.46	0.03

CERES (After)	Ice	Water	Ice	Water	Ice	Water
%	23.97	76.02	85.11	14.89	26.13	73.87

After Enhancement



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→ 131, 385 pixels

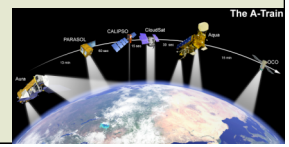
Before Enhancement

CERES (Before)	Clear	Ice	Water	NoRet	Bad Data
%	71.42 (%)	10.5 (%)	15.59 (%)	2.46	0.03

Majority of missing clouds are water

CERES (After)	Ice	Water	Ice	Water	Ice	Water
%	23.97	76.02	85.11	14.89	26.13	73.87

After Enhancement



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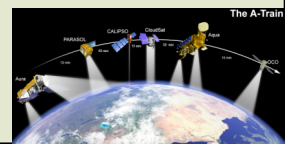
CERES (After)	Ice	Water	Ice	Water	Ice	Water
%	23.97	76.02	85.11	14.89	26.13	73.87

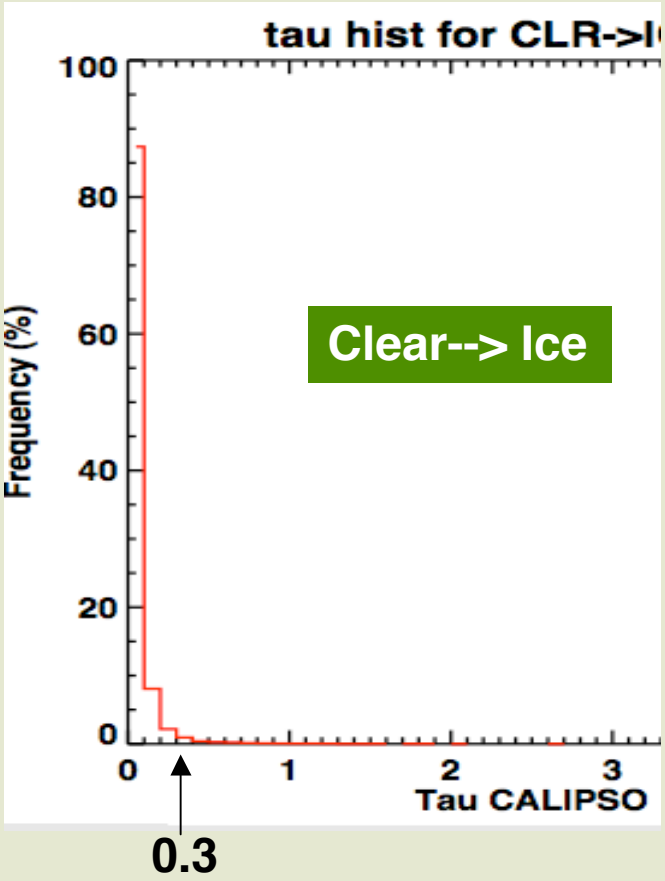
After Enhancement

CERES phase successful rate ~ 80%



Each Phase Category of CALIPSO Optical Depth > 0.3 and <= 0.3

CALIPSO Tau / CERES (before-->after)	Greater than 0.3 (%)	Less than 0.3 (%)
Clear-->Ice (24%)	2.25	97.75
Clear-->Water (76%)	35.39	64.61
Ice-->Ice (85%)	53.46	46.54
Ice-->Water (15%)	59.25	40.75
Water-->Ice (26%)	22.13	77.87
Water-->Water (74%)	64.94	35.06

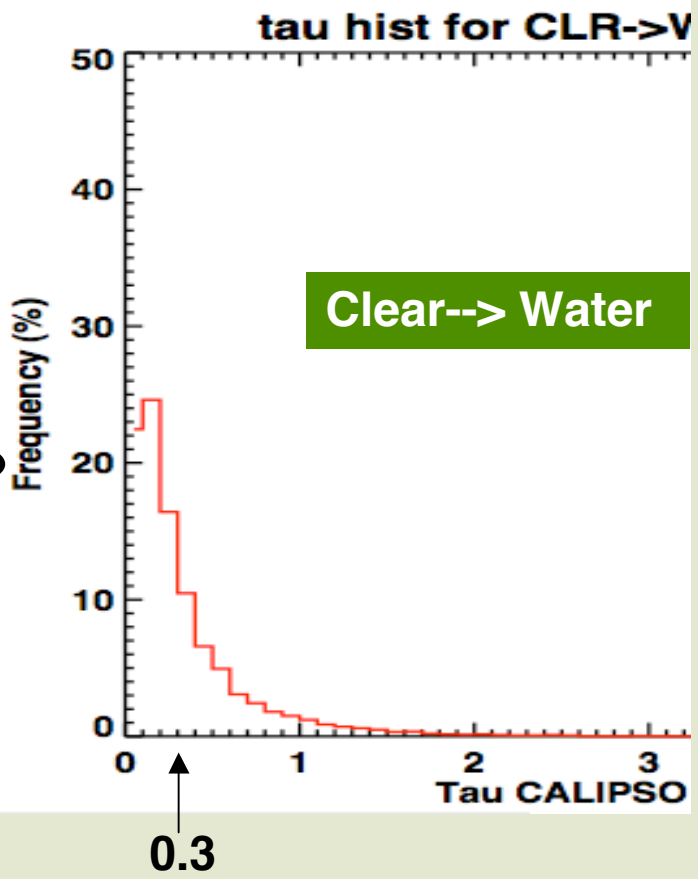


Almost all the missing ice clouds are the clouds with tau < 0.3

We have picked all the ice clouds that we possiblly could based on MODIS sensitivity

Each Phase Category of CALIPSO Optical Depth > 0.3 and <= 0.3

CALIPSO Tau / CERES (before-->after)	Greater than 0.3 (%)	Less than 0.3 (%)
Clear-->Ice (24%)	2.25	97.75
Clear-->Water (76%)	35.39	64.61
	CF ~ 4%	CF ~ 7%
Ice-->Ice (85%)	53.46	46.54
Ice-->Water (15%)	59.25	40.75
Water-->Ice (26%)	22.13	77.87
Water-->Water (74%)	64.94	35.06



Assuming CF for single transparent cloud ~ 20%, then CF for missing water cloud with tau > 0.3 is ~ 4% (0.2 x 0.71 x 0.76 x 0.35), missing water CF ~ 7% for tau < 0.3.

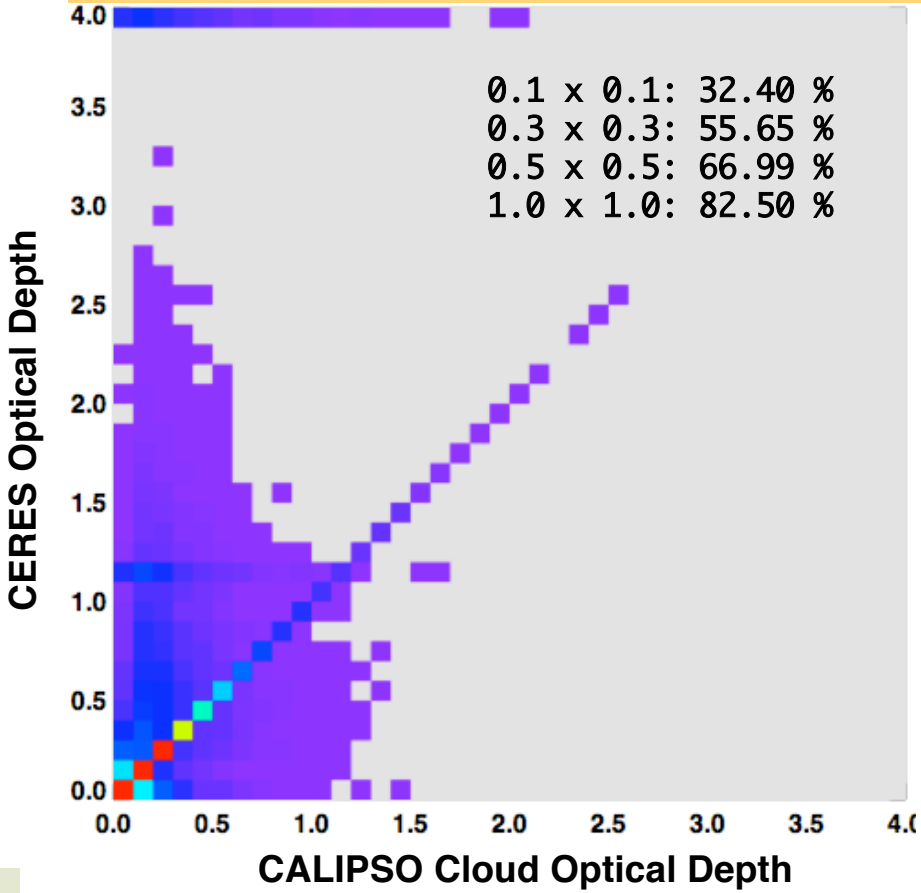
Cloud Phase Comparisons between CALIPSO and CERES

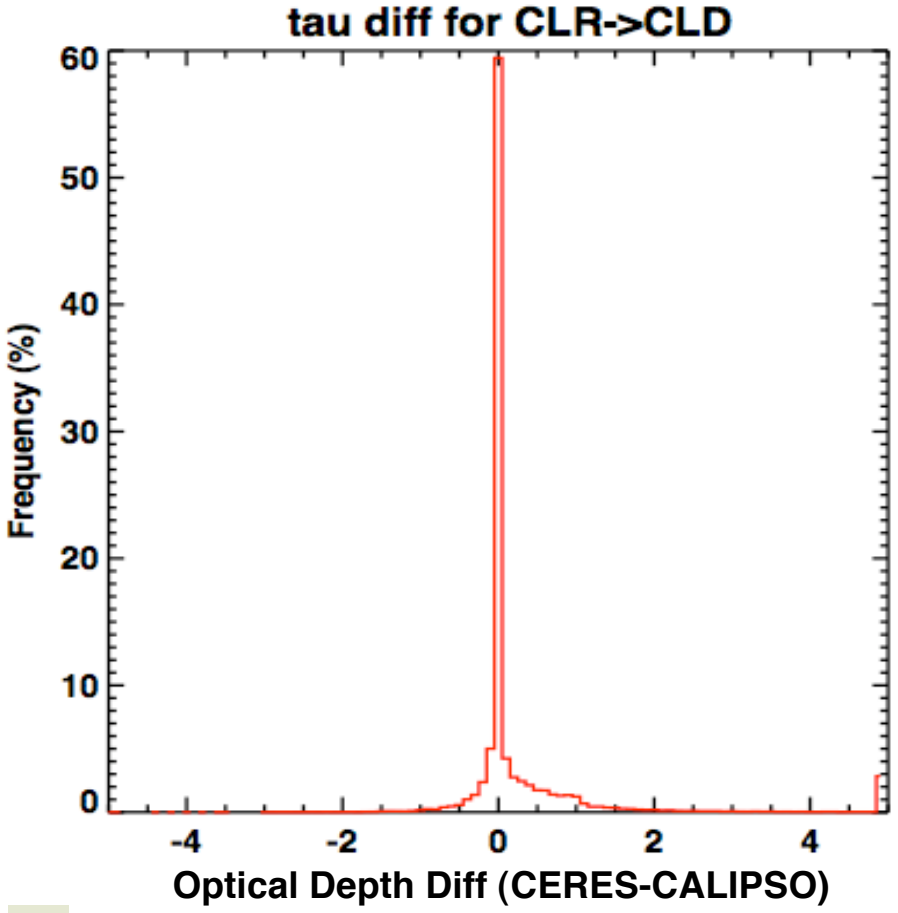
CALIPSO Phase / CERES (before-->after)	Ice (%)	Water (%)	Undetermined (%)
Clear-->Ice (24%)	81.87	12.5	5.62
Clear-->Water (76%)	16.58	52.7	30.73
Ice-->Ice (85%)	94.07	4.25	1.68
Ice-->Water (15%)	9.54	69.86	20.60
Water-->Ice (26%)	80.22	14.97	4.81
Water-->Water(74%)	17.82	60.89	21.29

- CALIPSO is confident with it's ice phase
- Enhanced CERES ice cloud phase is ~ 80-95 % in agreement with CALIPSO ice phase

CERES Optical Depth After the Enhancement Compared with CALIPSO Optical Depth

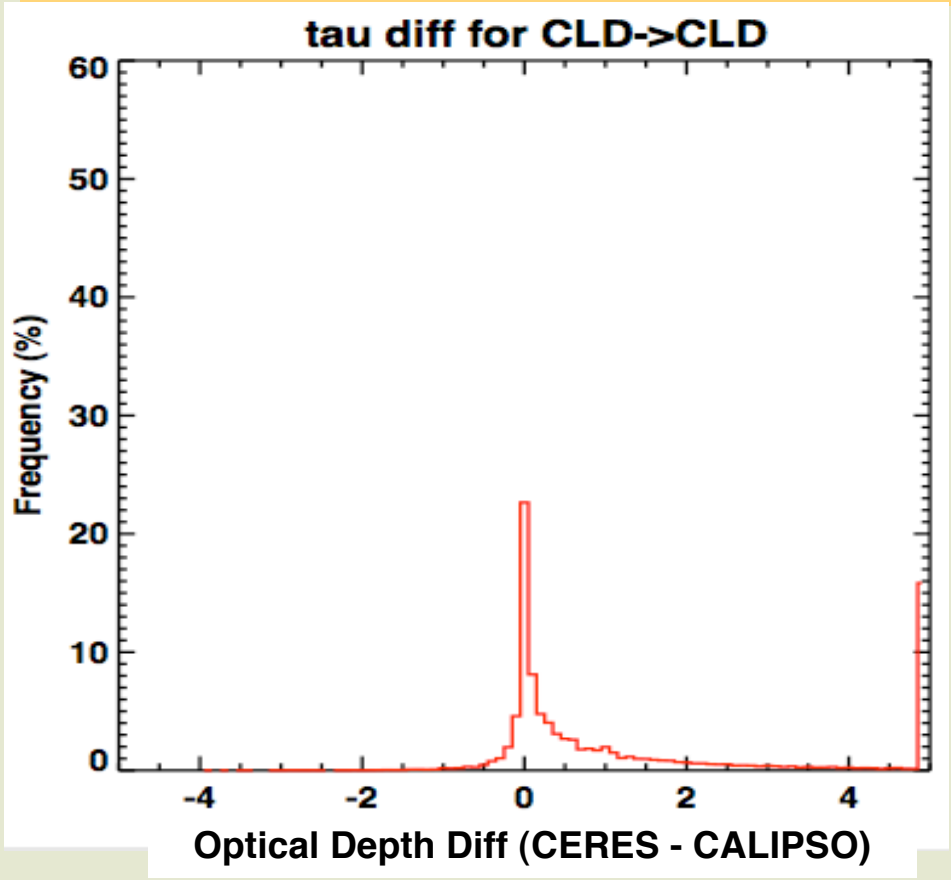
Clear (before enhancement) ---> Cloud (after enhancement)

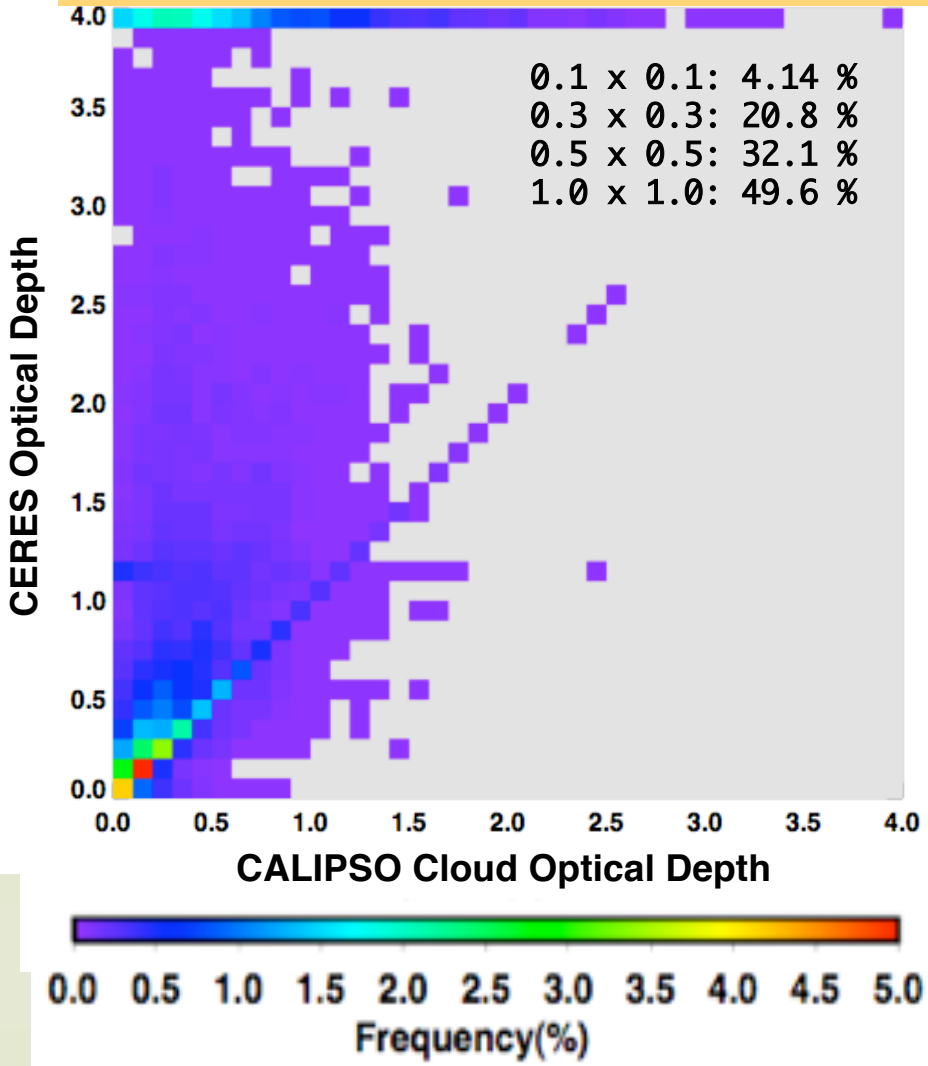




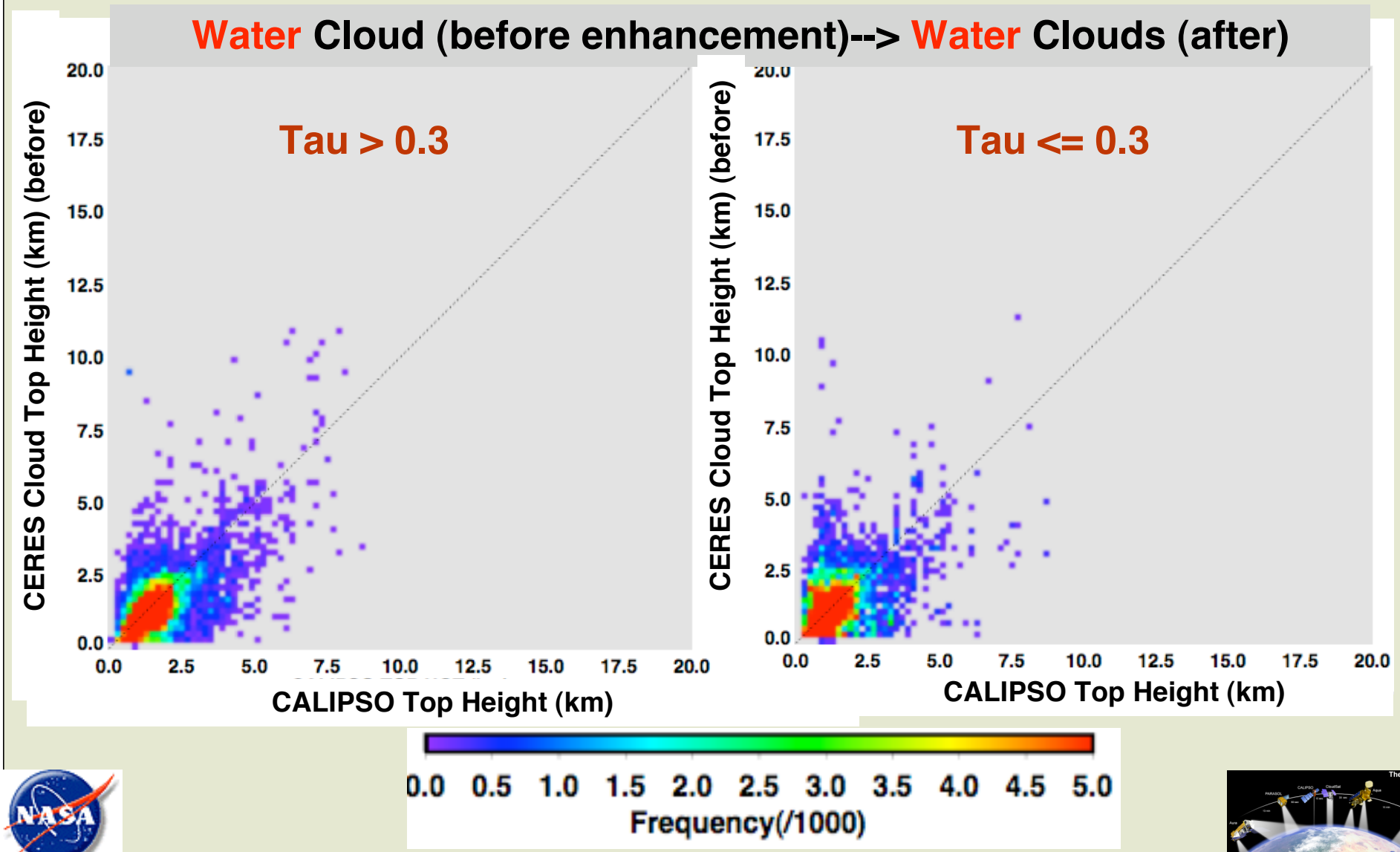
CERES Optical Depth After the Enhancement Compared with Calipso Optical Depth

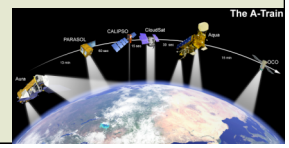
Cloud (before enhancement)--> cloud (after enhancement)





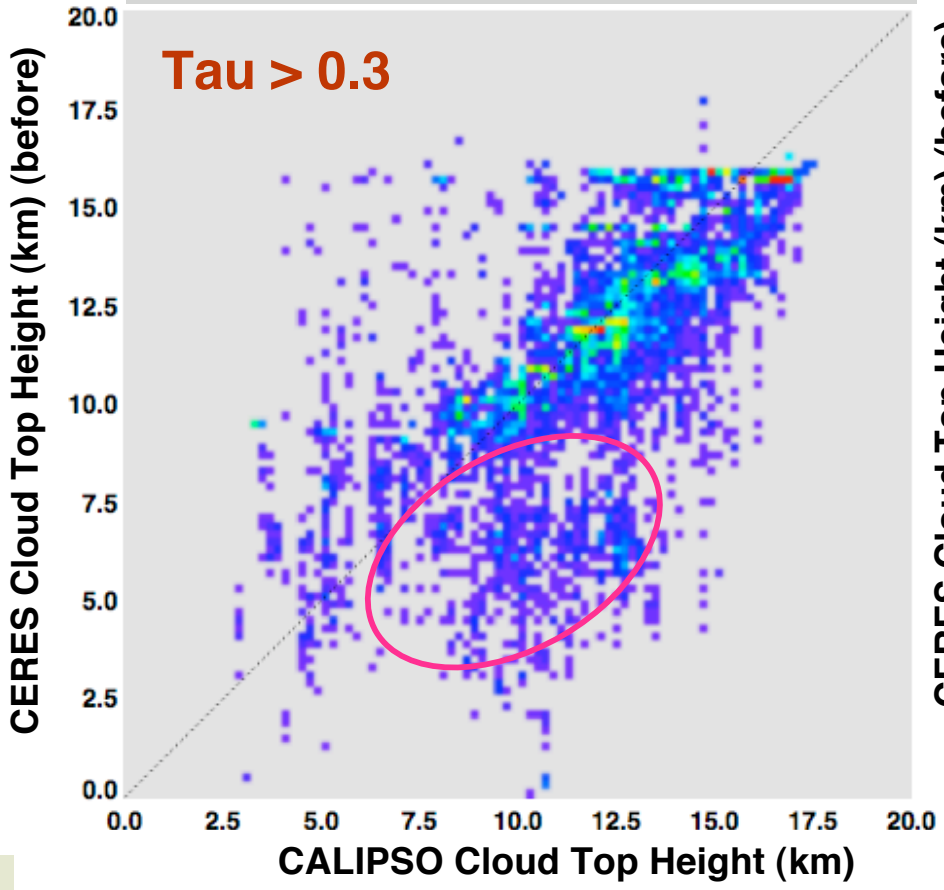
CERES Cloud Top Height Before the Enhancement Compared with Calipso Cloud Top Height

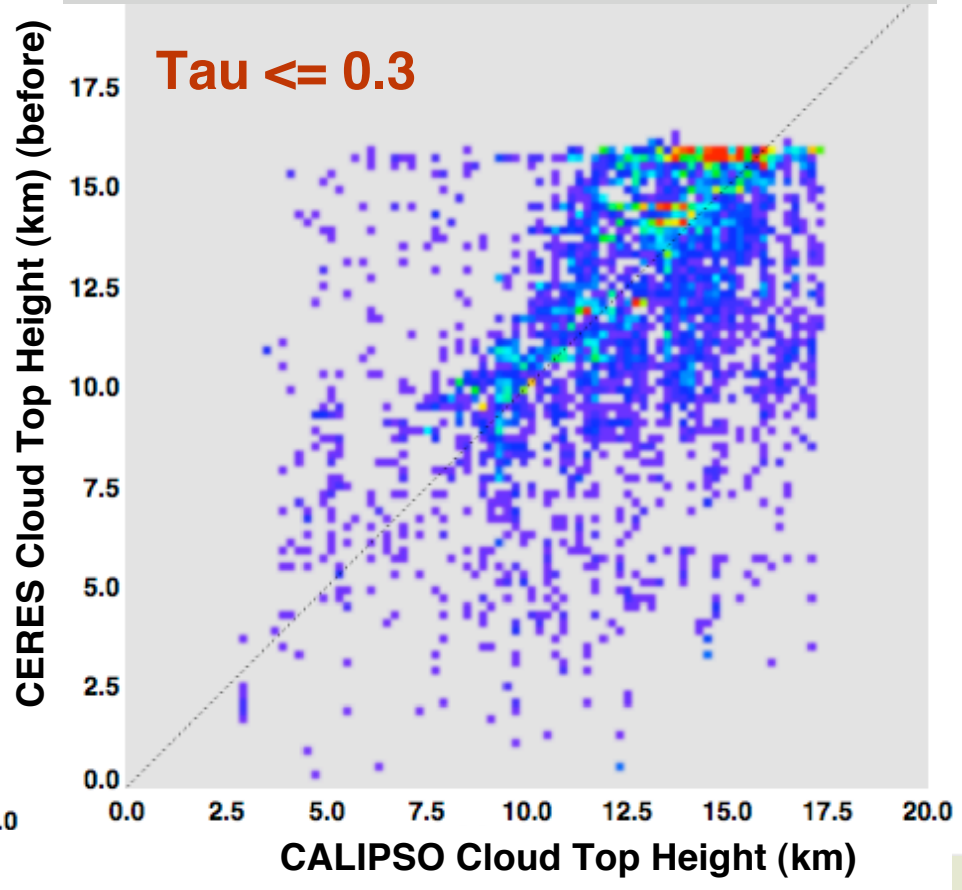


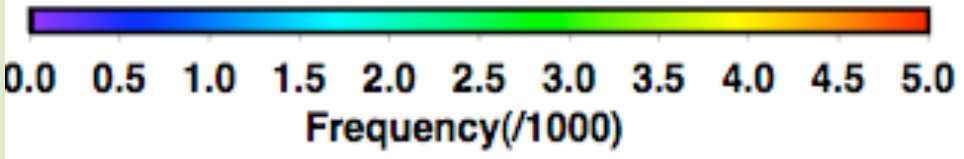


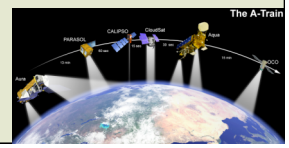
CERES Cloud Top Height Before the Enhancement Compared with Calipso Cloud Top Height

Ice Cloud (before enhancement)--> Ice Clouds (after)



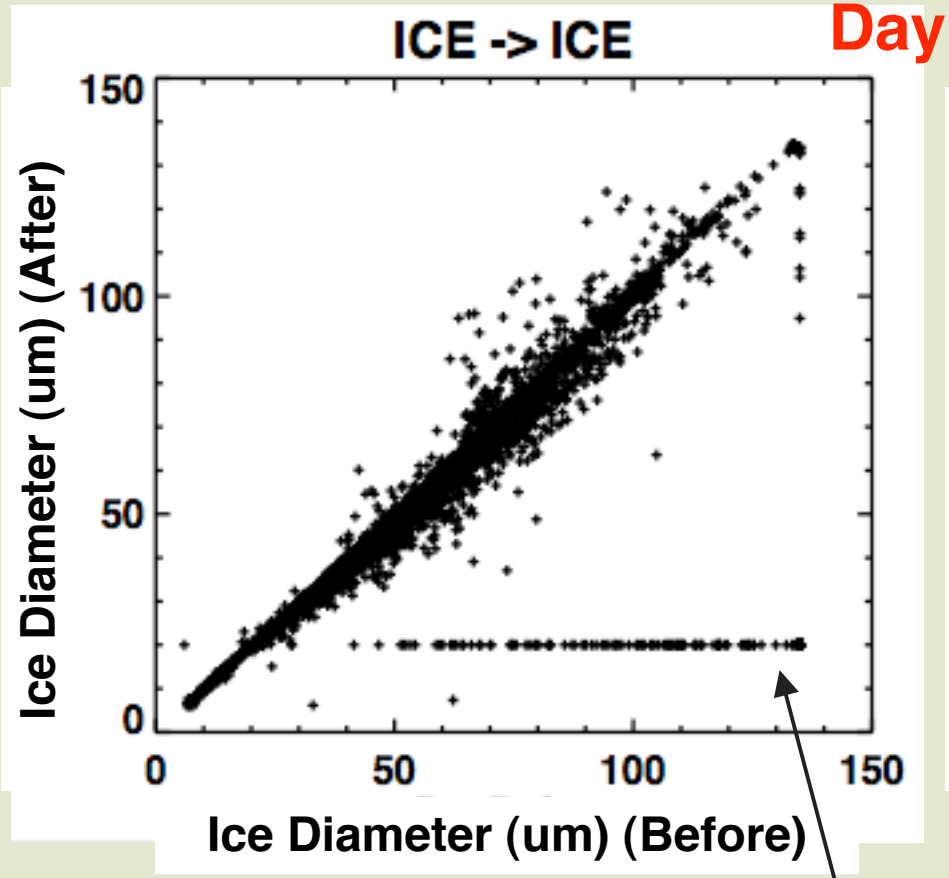


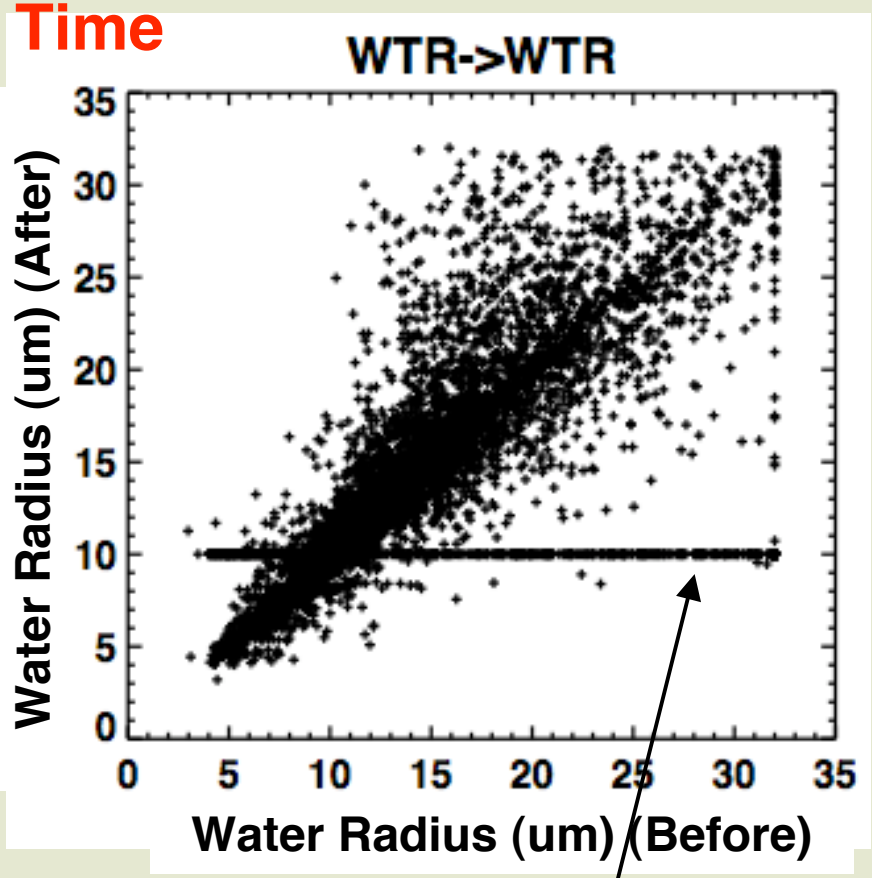




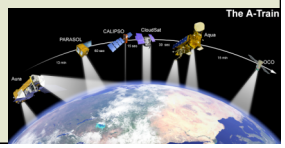
CERES Cloud Particle Size Comparisons (Before and After the Enhancement)

Day Time





After the enhancement, if still no retrieval De=20 um and re=10 um



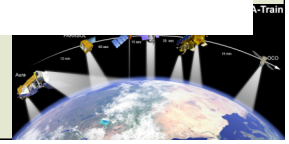
Summary and Future Plan

For single transparent layer, tau < 4, non-polar region:

- **Almost all the CERES missing ice cloud (~ 3%) is thin cirrus with tau < 0.3**

- **Missing water cloud fraction ~ 4% for tau > 0.3 (room to improve for CERES), 7% for tau < 0.3**

- **Enhanced CERES ice cloud phase ~ 80-95 % in agreement with CALIPSO ice phase**

- **After the enhancement, all CERES cloud properties have some correlation with CALIPSO.**

- **The results are very preliminary, only 3 days. Need to look at the more data, more months or years, separated by day / night, ocean / land, polar / non-polar….**