

Build 3D Cloud Properties with A-Train C3M data

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Outline

- Motivation
- 3D-Cloud-Field Construction Algorithm used in C3M data
- Some imagery results of 3D-Cloud-Field
- Examination of MODIS channels used in 3D-Cloud-Field
- Assessment of constructed 3D cloud properties using a month of C3M data
- Summary



Data Used in this study

One month (April 2013) of C3M Pixel Level Data

C3M:

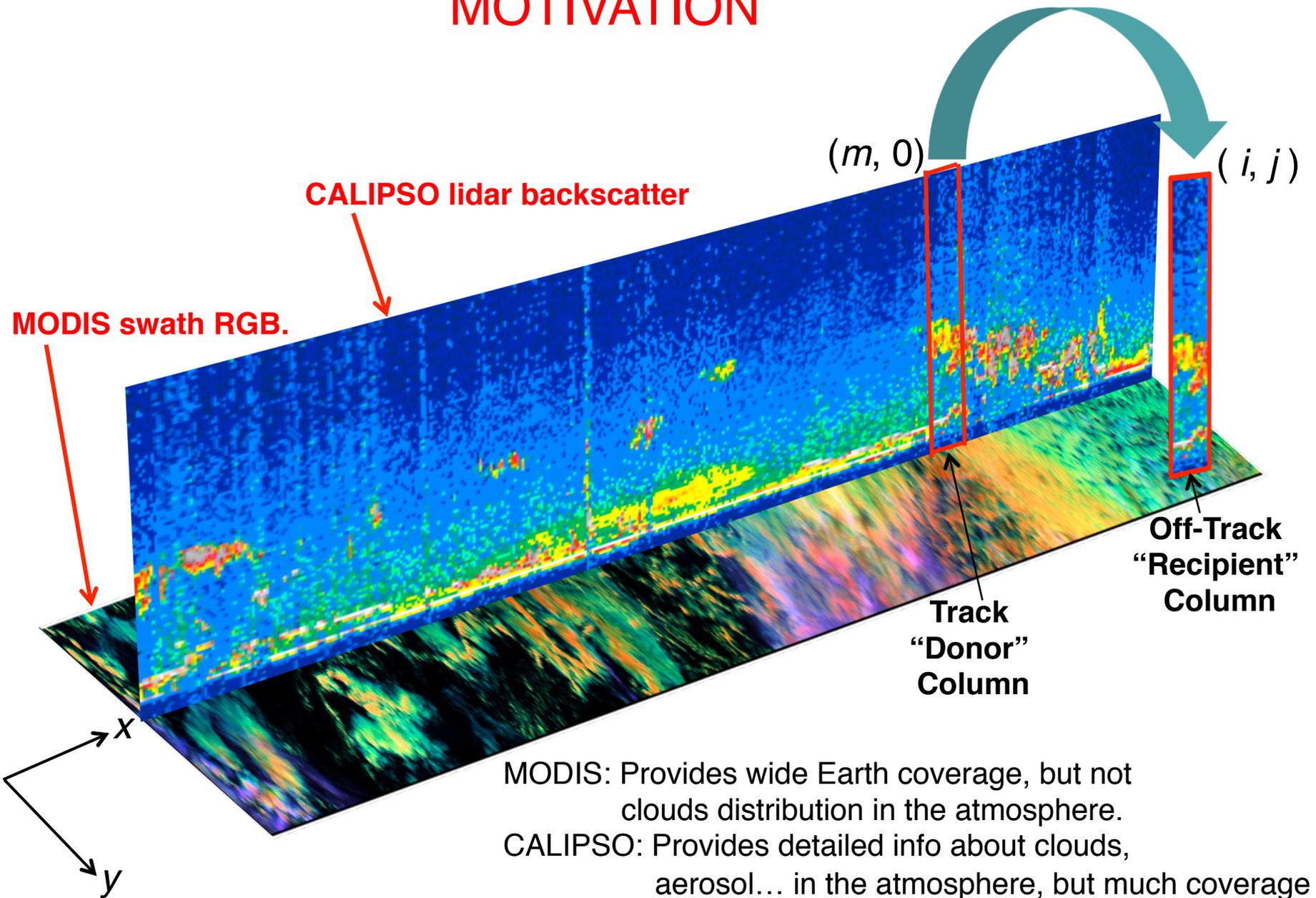
Merged CALIPSO, CloudSat, CERES and MODIS

where

MODIS: CERES derived cloud properties with
MODIS data



MOTIVATION



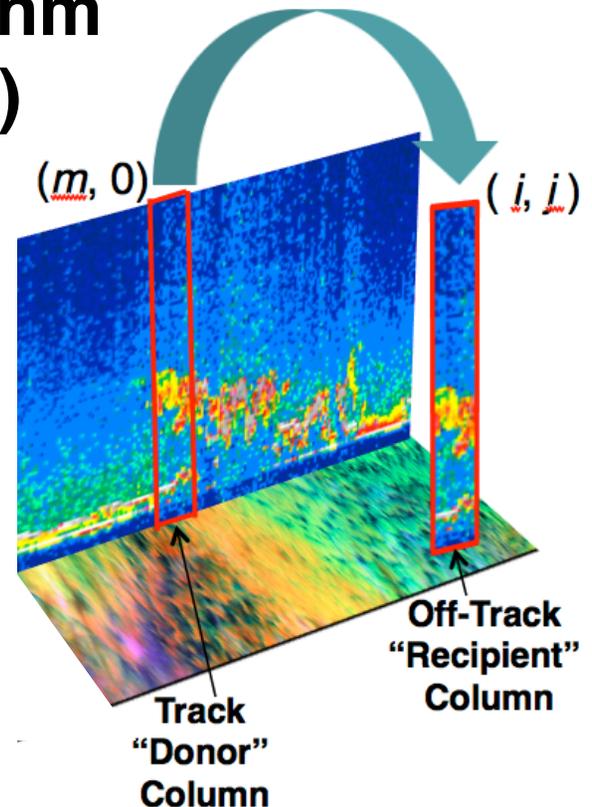
3D Cloud-Field Construction Algorithm

Cost Function (Barker et al., 2011, QJRMS)

$$F(i, j; m) = \sum_{k=1}^4 \left[\frac{r_k(i, j) - r_k(m, 0)}{r_k(i, j)} \right]^2, \quad m \in [i-100, i+100]$$

MODIS spectral radiance of recipient pixel at channel k

MODIS spectral radiance of donor pixel at channel k



Column:
CALIPSO, CloudSat,
CERES and MODIS data

1. Donors searching range, m , for each recipient (i, j) : $i-100$ ----- $i+100$
2. Surface types at $(m, 0)$ and (i, j) must be same
3. Calculate Cost Function with k (MODIS channels): 0.6, 2.1, 8.6 and $12 \mu\text{m}$
4. Among 3% of the smallest $F(i, j, m)$, the shortest distance from donor to recipient \rightarrow final donor for recipient (i, j) .

Without 3D:

CERES derived cloud properties with MODIS swath data

With 3D-Orig Chan:

Barker et al., 2011, QJRMS, with original 4 channel:

0.6, 2.1, 8.6 and 12 μm

(Day and Night, Snow / Ice-Free Ocean / Land)



Some 3D Cloud Field Imagery Results



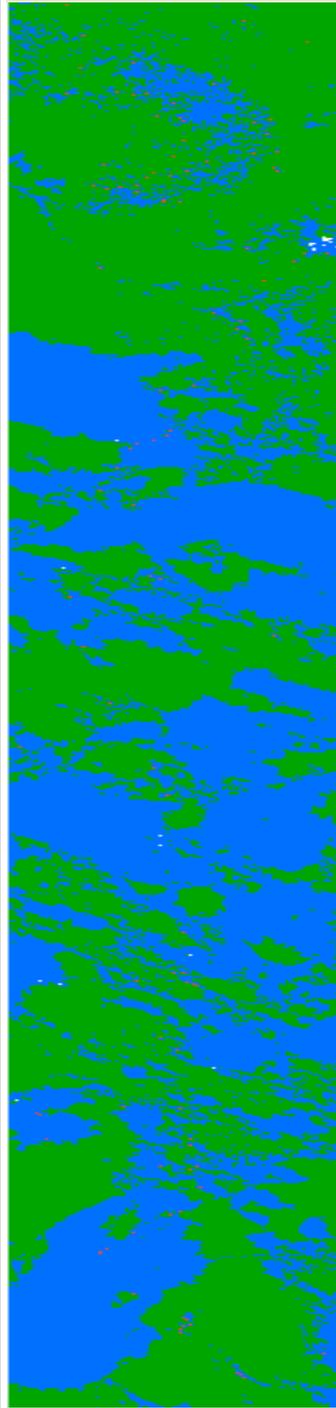
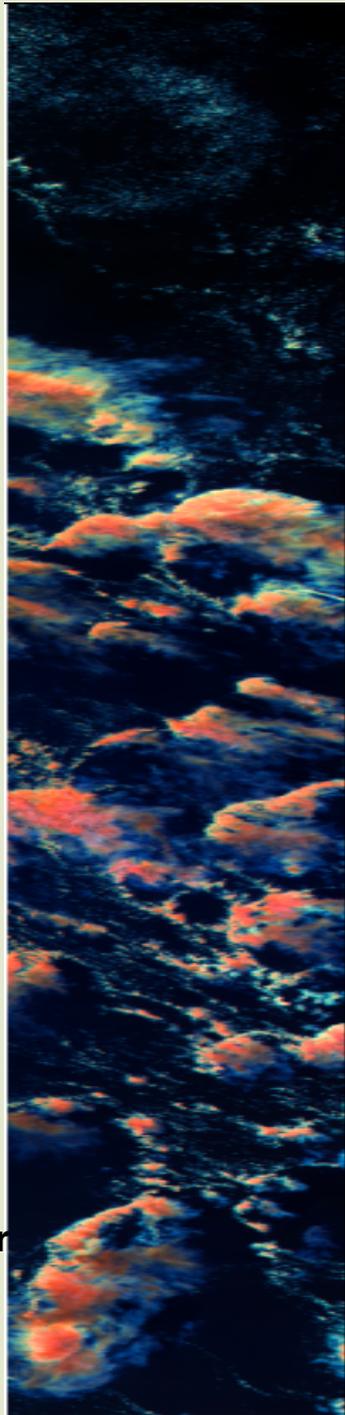


Aqua MODIS
2013 04 01
02h 25min
Pacific Ocean

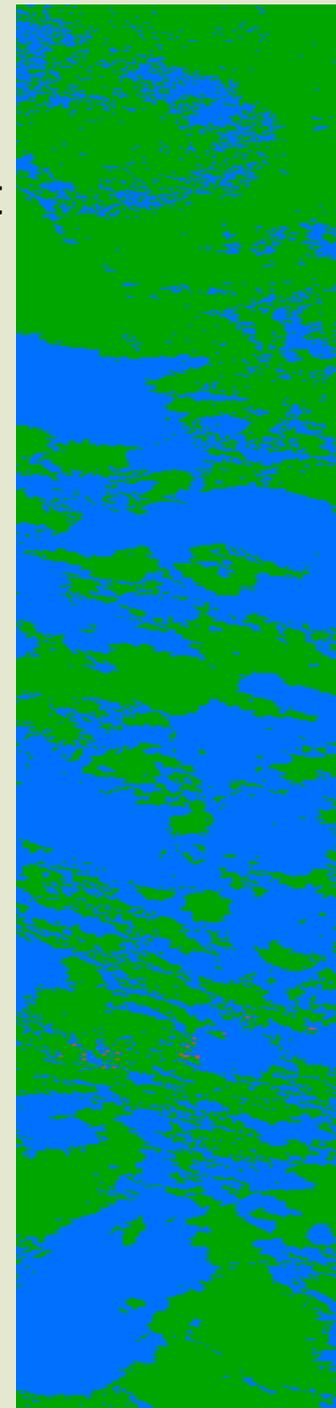
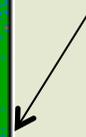
Day Time
Snow/Ice Free
Ocean



water ice noRetr clear

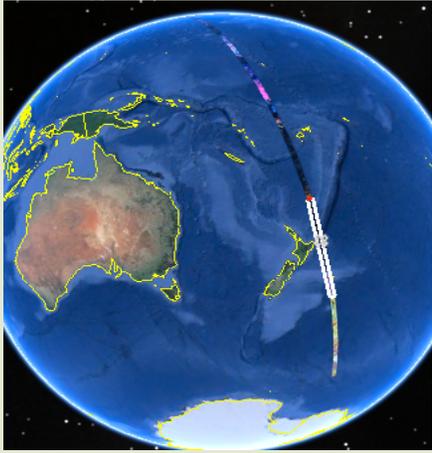


Cloud
Phase
without
3D



Cloud
Phase
With-3D
using
original 4
chan

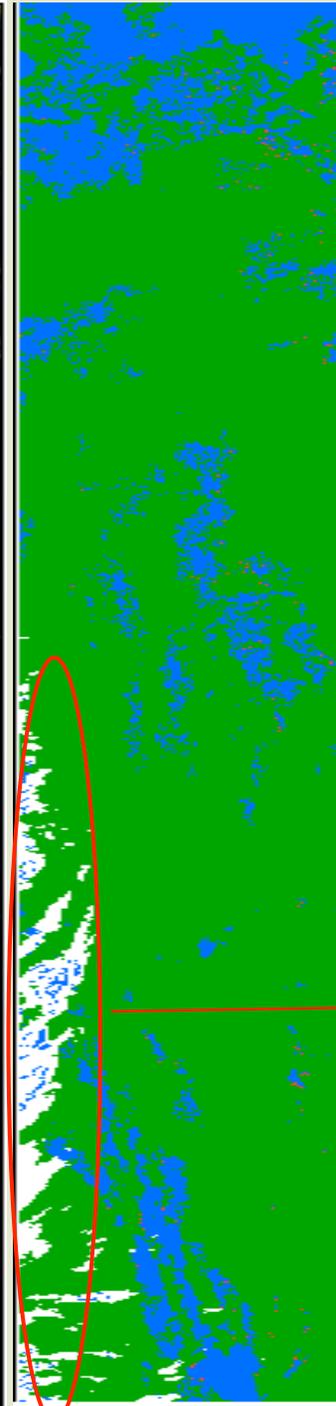
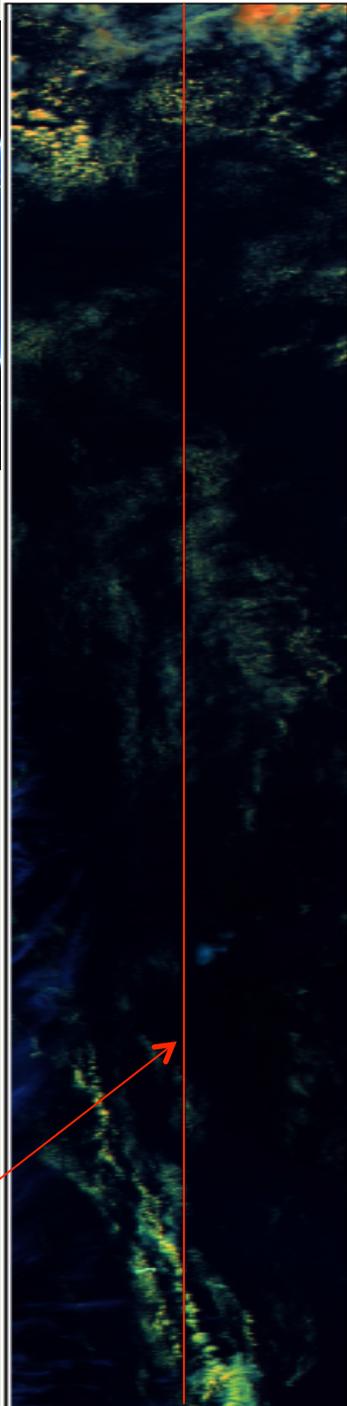




Aqua MODIS
2013 04 01
02h 10min
Pacific Ocean
Day Time

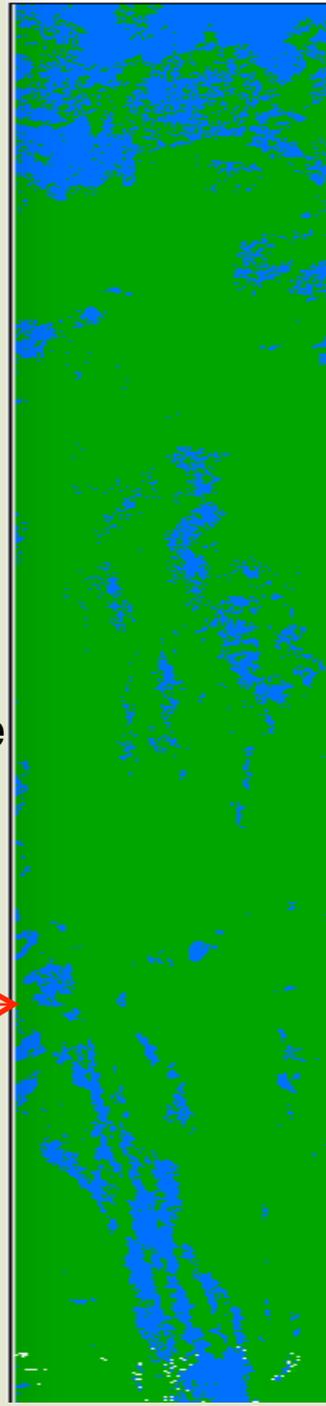


CALIPSO track



Cloud Phase without 3D

Missed ice clouds. No ice clouds on the track



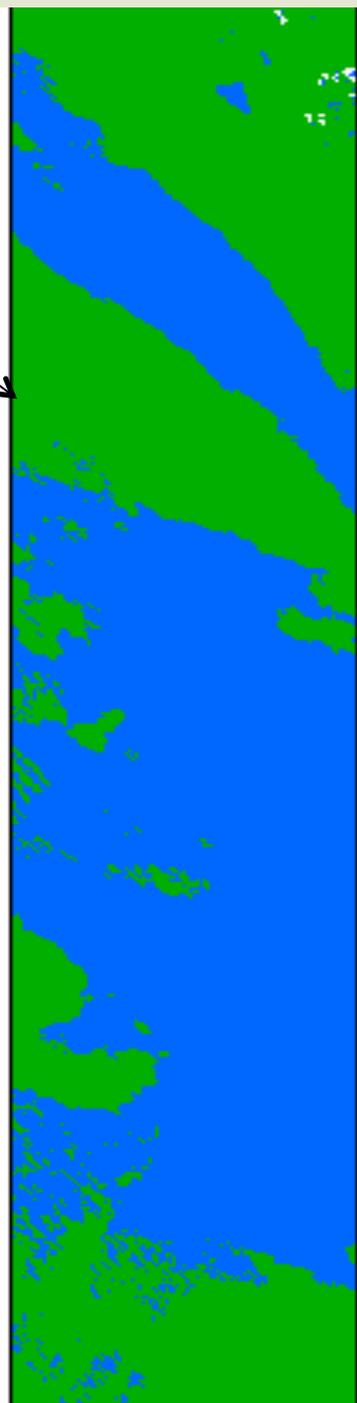
Cloud Phase with 3D using original 4 chan



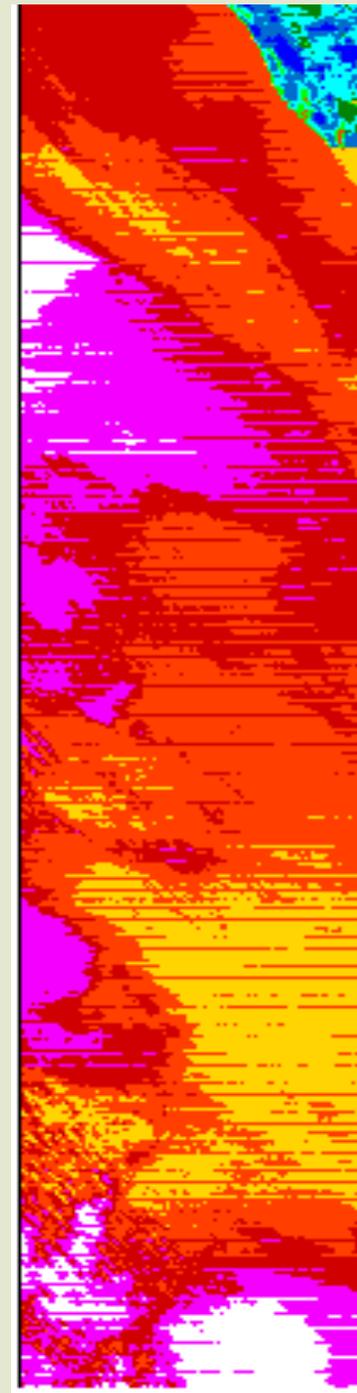
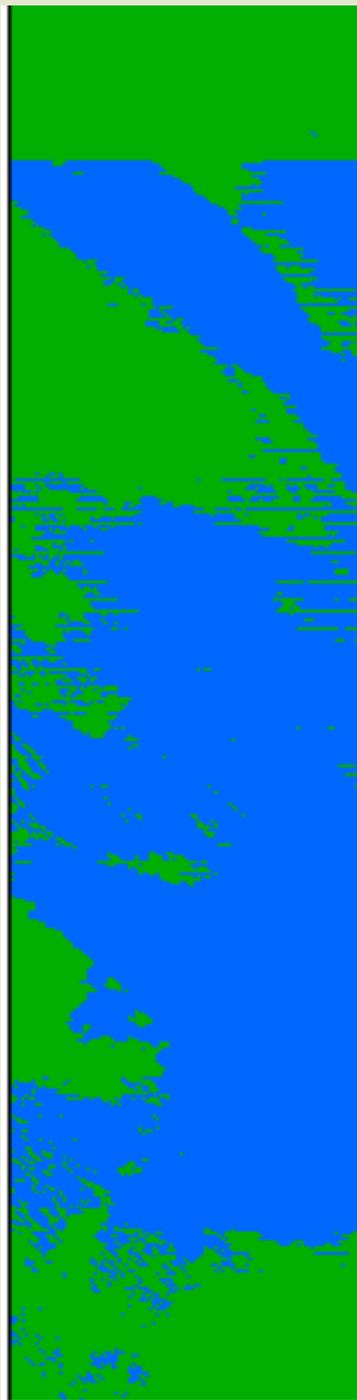
Issues in 8.6 μm channel



Cloud Phase without 3D



Cloud Phase with 3D using original 4 chan



BTemp (K)
8.6 um





Aqua MODIS
2013 04 22
00h 10 min

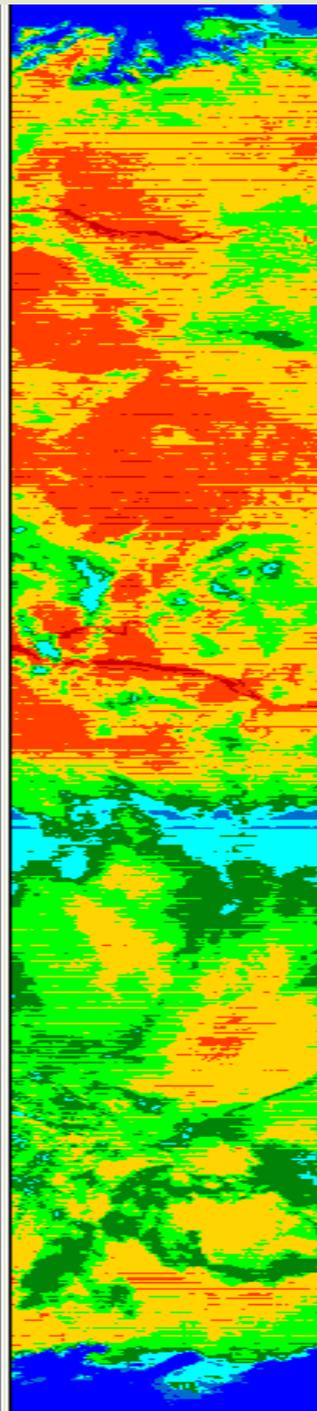
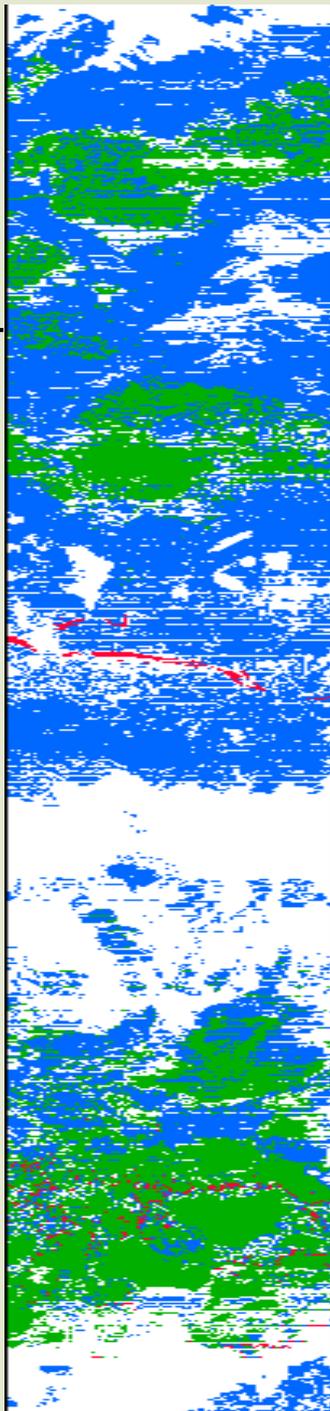


water ice noRetr clear

Night Time

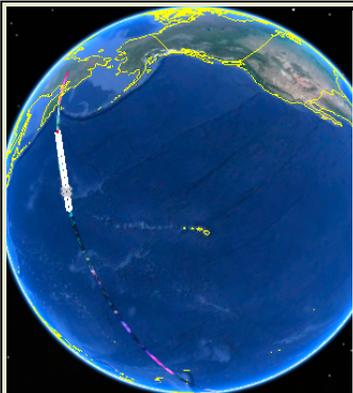


Cloud
Phase
with 3D
using
original 4
chan

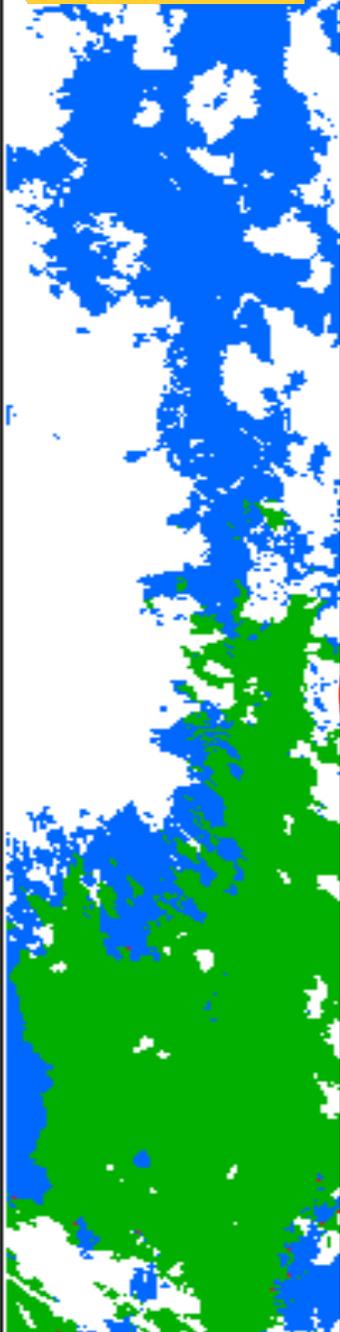


BTTemp
(K)
8.6 um

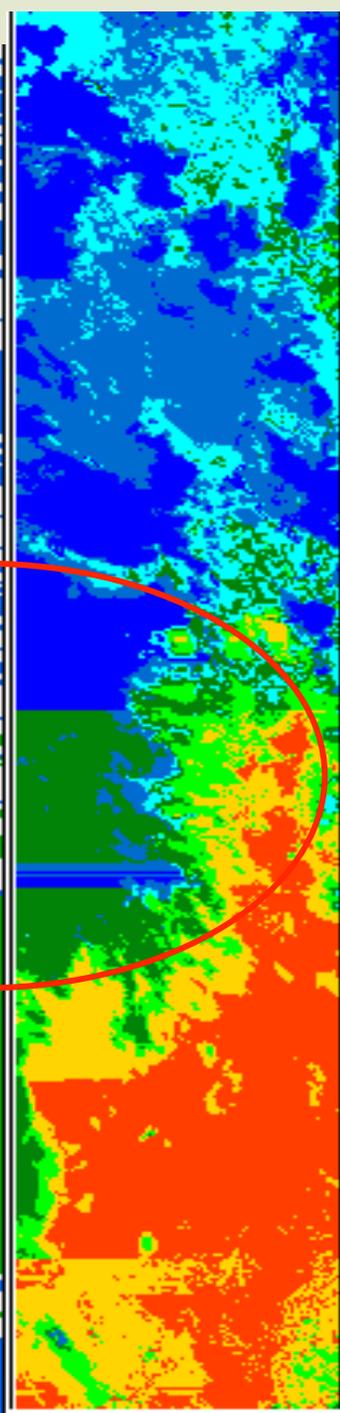
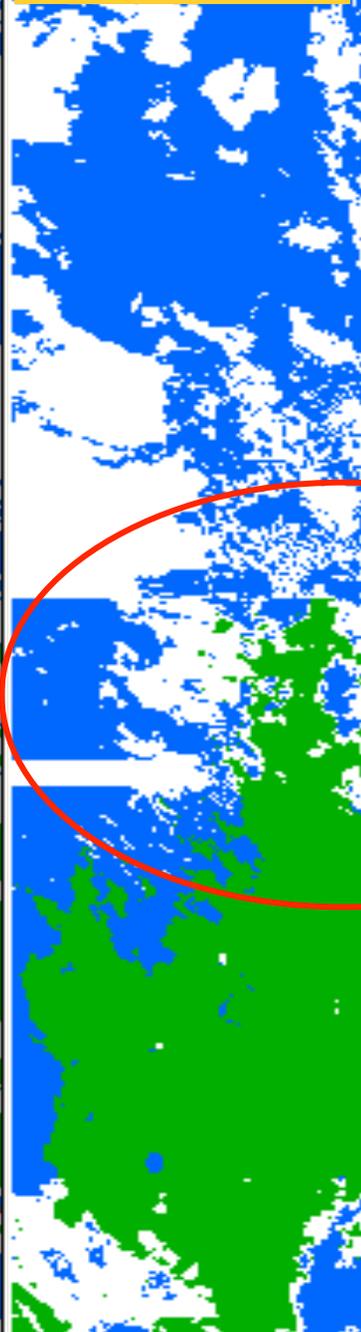




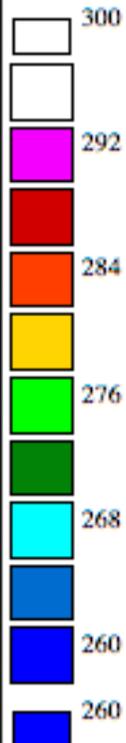
Without 3D



3D-Orig Chan



8.6 um
BTemp



With 3D:

Barker et al., 2011, QJRMS, with updated 4 Chan:

- Day Time over Snow / Ice-Free sfc:
0.6, 3.7, 11 and 12 μm
- Day Time over Snow / Ice Covered sfc:
1.24, 2.1, 3.7, and 11 μm
- Night Time over All sfc:
2.1, 11, 12, 13.3 μm

Without 3D: MODIS Swath Cloud Properties Retrieved by
CERES Cloud Retrieval

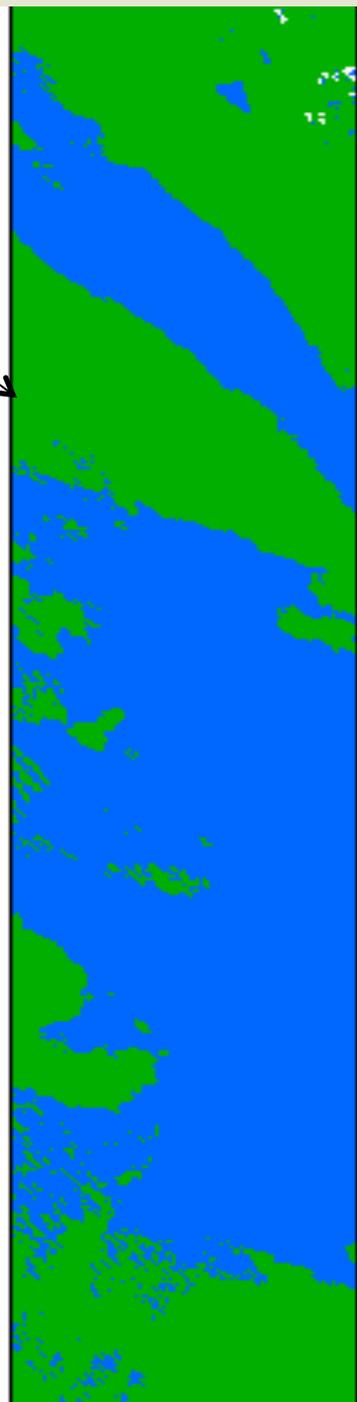
With 3D-Orig Chan:

Barker et al., 2011, QJRMS, with original 4 channel:

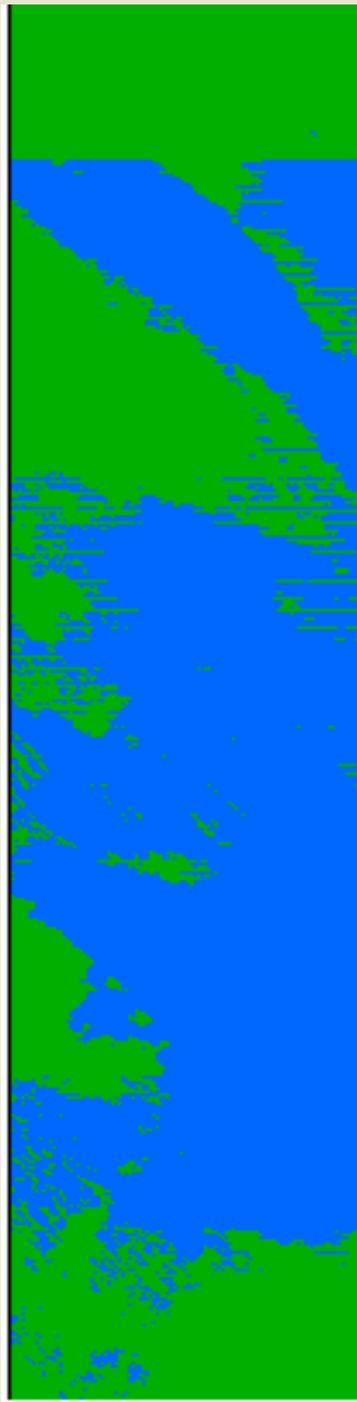
0.6, 2.1, 8.6 and 12 μm
(Day and Night, Snow / Ice-Free sfc)



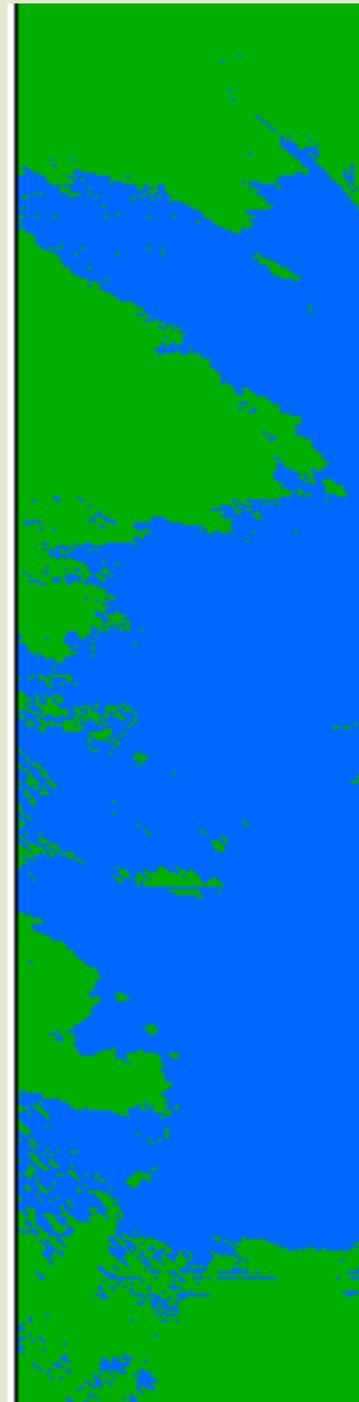
Cloud Phase without 3D



Cloud Phase with 3D using original 4 chan

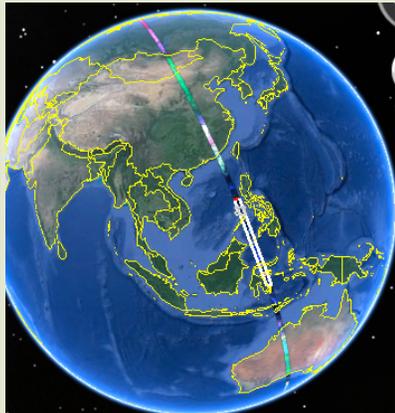


Cloud Phase with 3D

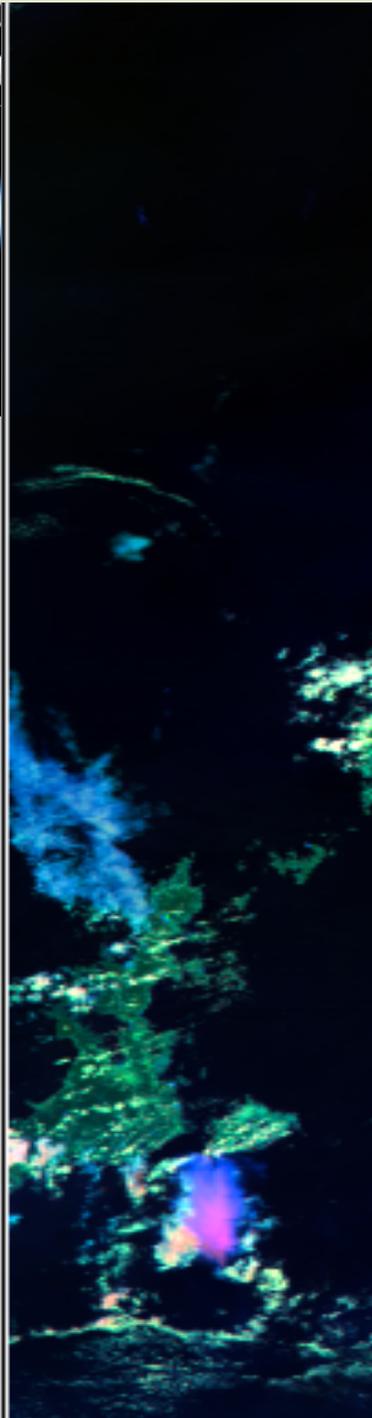


water ice noRetr clear

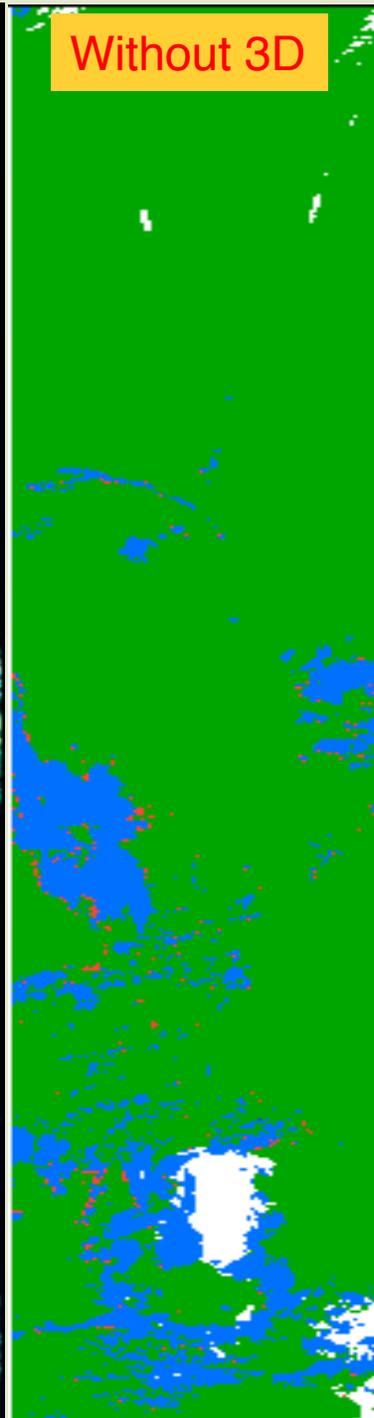




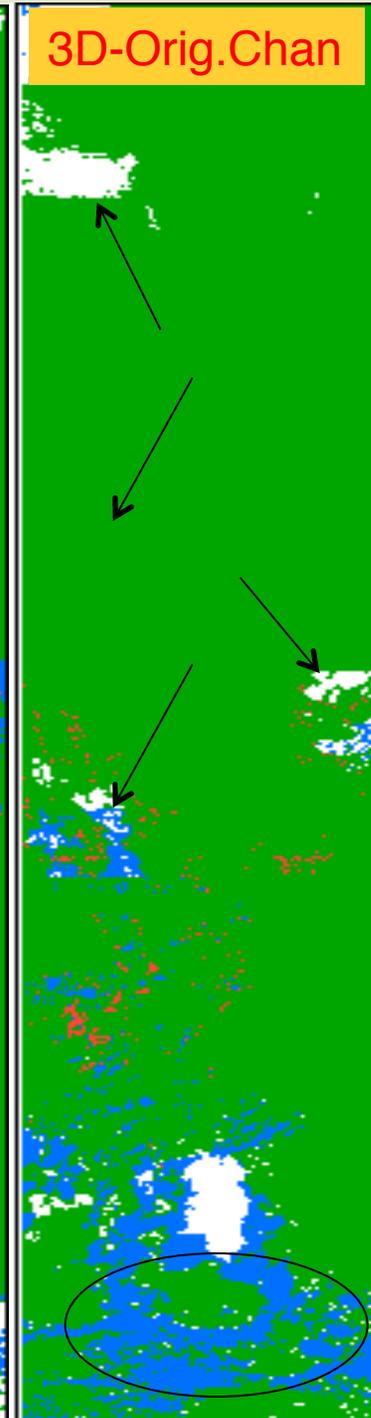
2013 04
01 05
40min



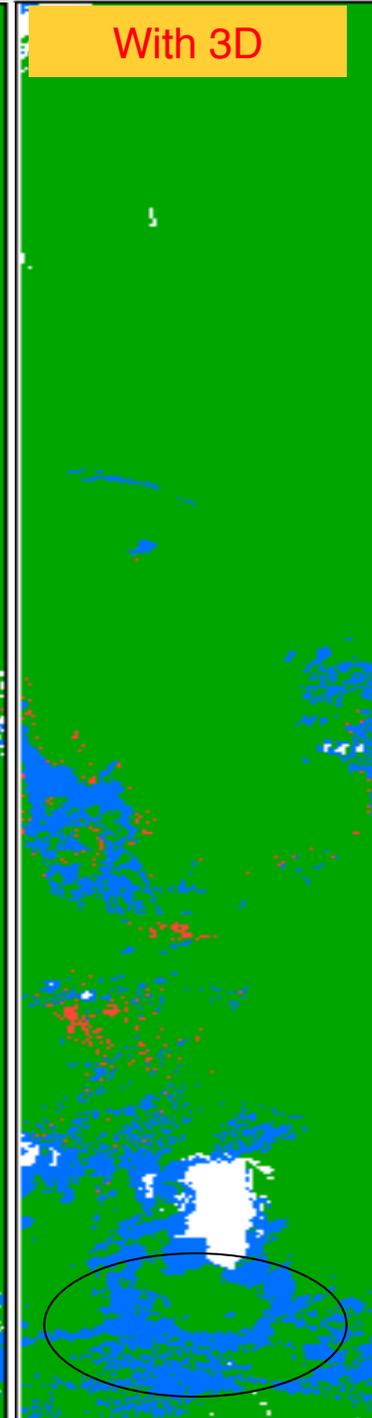
Without 3D



3D-Orig.Chan



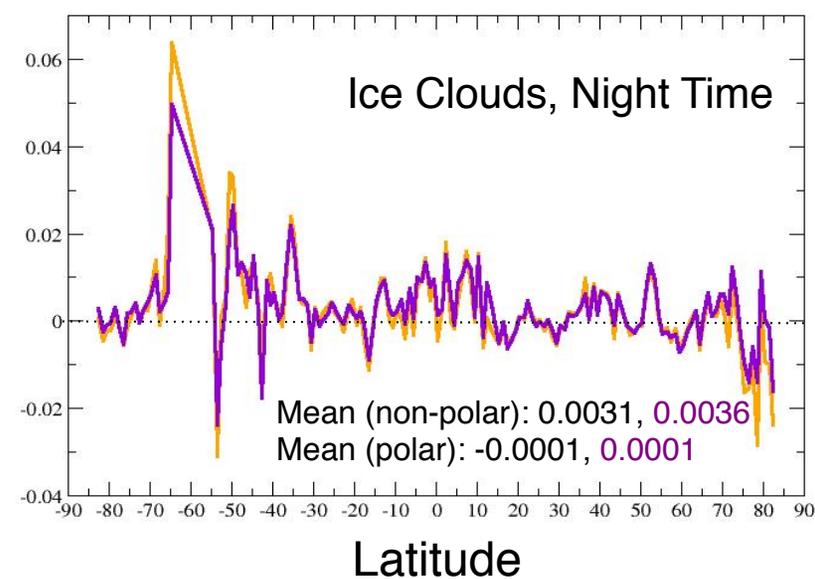
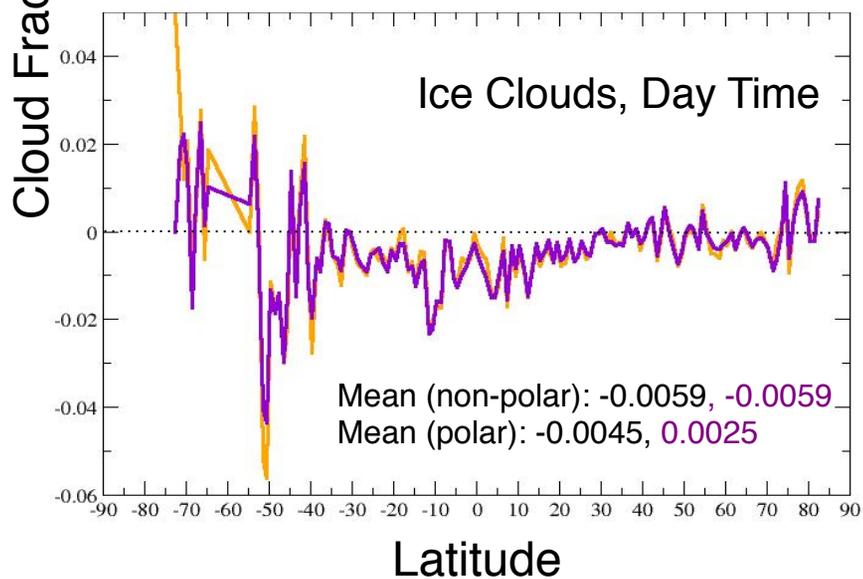
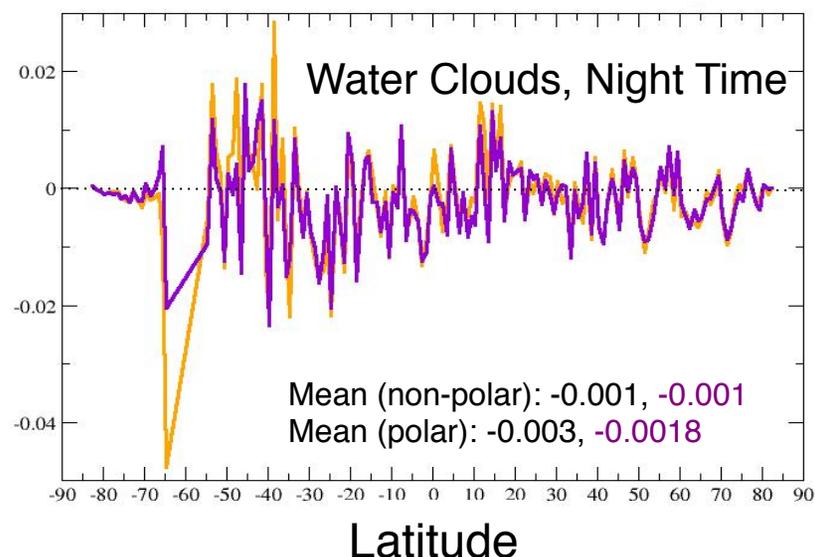
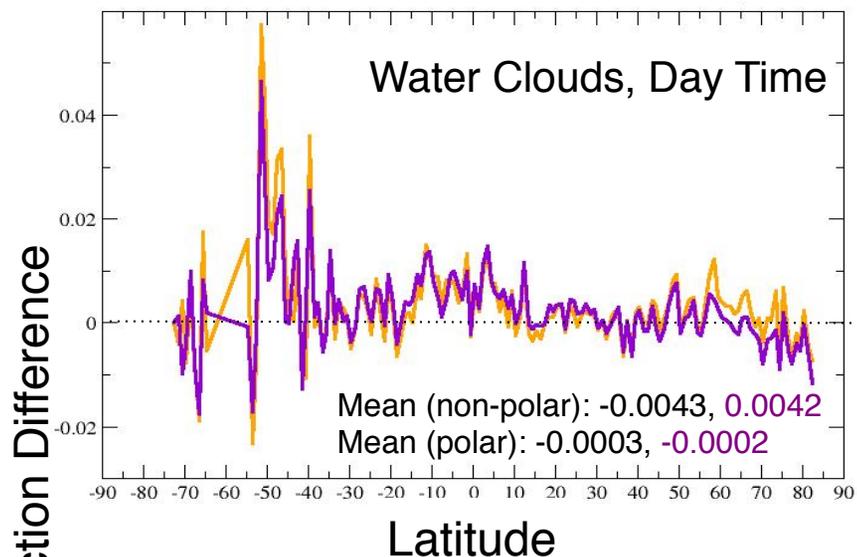
With 3D



Zonal Cloud Fraction Difference

— With 3D (Orig. 4 chan) – Without 3D
— With 3D – Without 3D

C3M, April 2013, Land



3D Cloud Fraction Assessment



Daytime, Cloud Mask, April 2013, n = 50

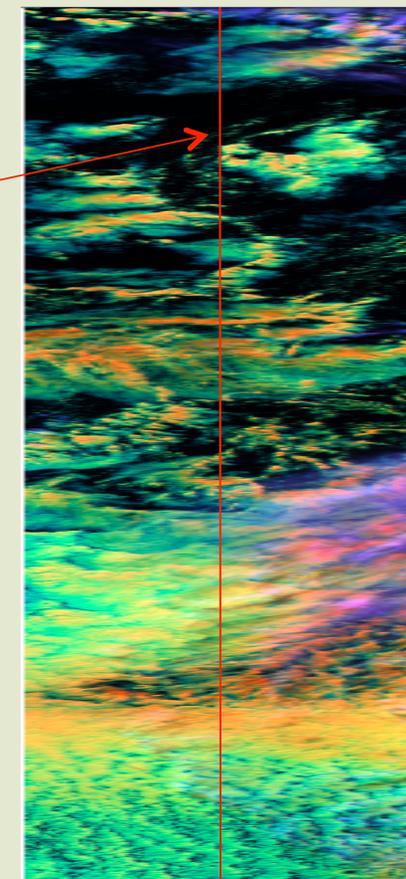
Ocean (ice-free)		Without 3D	
With 3D	Clear (%)	Cloud (%)	
Clear (%)	66.41	2.67	
Cloud (%)	2.56	28.36	
Agreement (%)	94.77		

n = Number of MODIS pixels or distance (km) from track that 3D cloud field is built on

Land (snow-free)		Without 3D	
With 3D	Clear (%)	Cloud (%)	
Clear (%)	48.65	3.26	
Cloud (%)	3.28	44.81	
Agreement (%)	93.46		

CALIPSO Track

← 101 pixels →

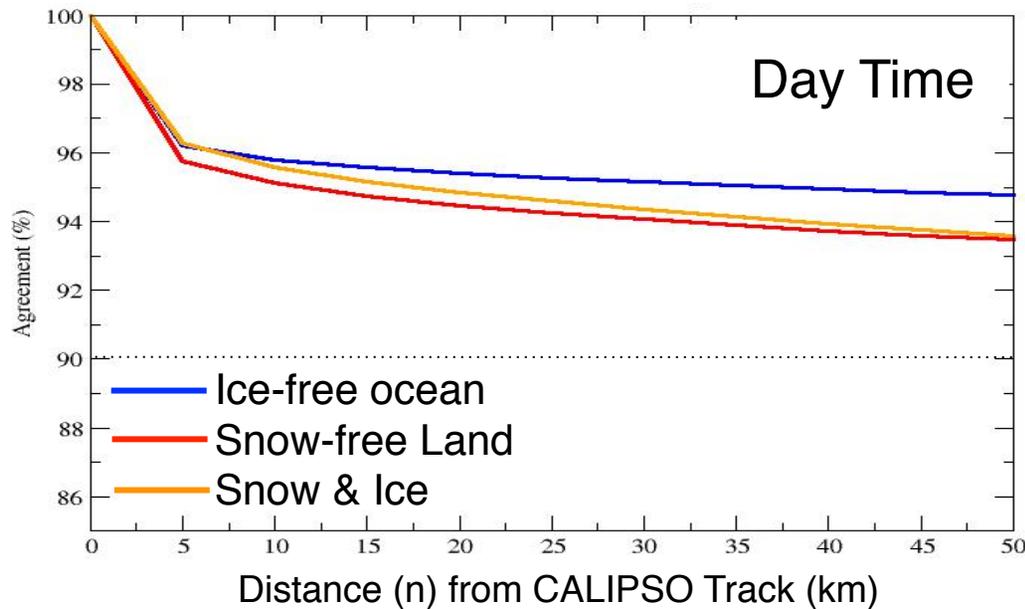


Snow / Ice covered sfc		Without 3D	
With 3D	Clear (%)	Cloud (%)	
Clear (%)	46.07	3.04	
Cloud (%)	3.38	47.51	
Agreement (%)	93.58		

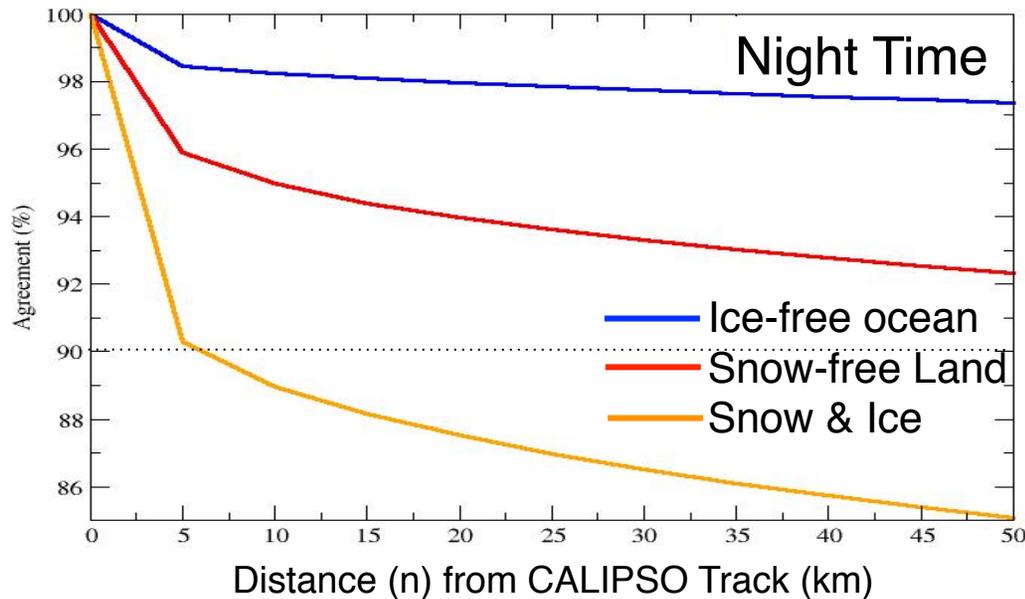
← n=50 →



Cloud Mask Agreement between 3D and without 3D



Cloud Mask Agreement between 3D and without 3D



Cloud Mask Agreement between with-3D and without-3D, as a function of n (distance from track).

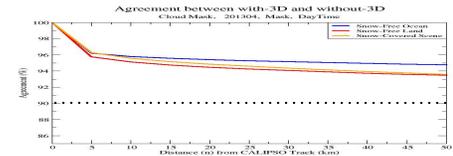
Mask:

- Agreement $> 92\%$ for all n's for all sfc types except night time over snow-ice
- Night time over snow-ice, agreement $\sim 90\%$ n=5, $\sim 87\%$ n=25 and drops to 85% when n=50

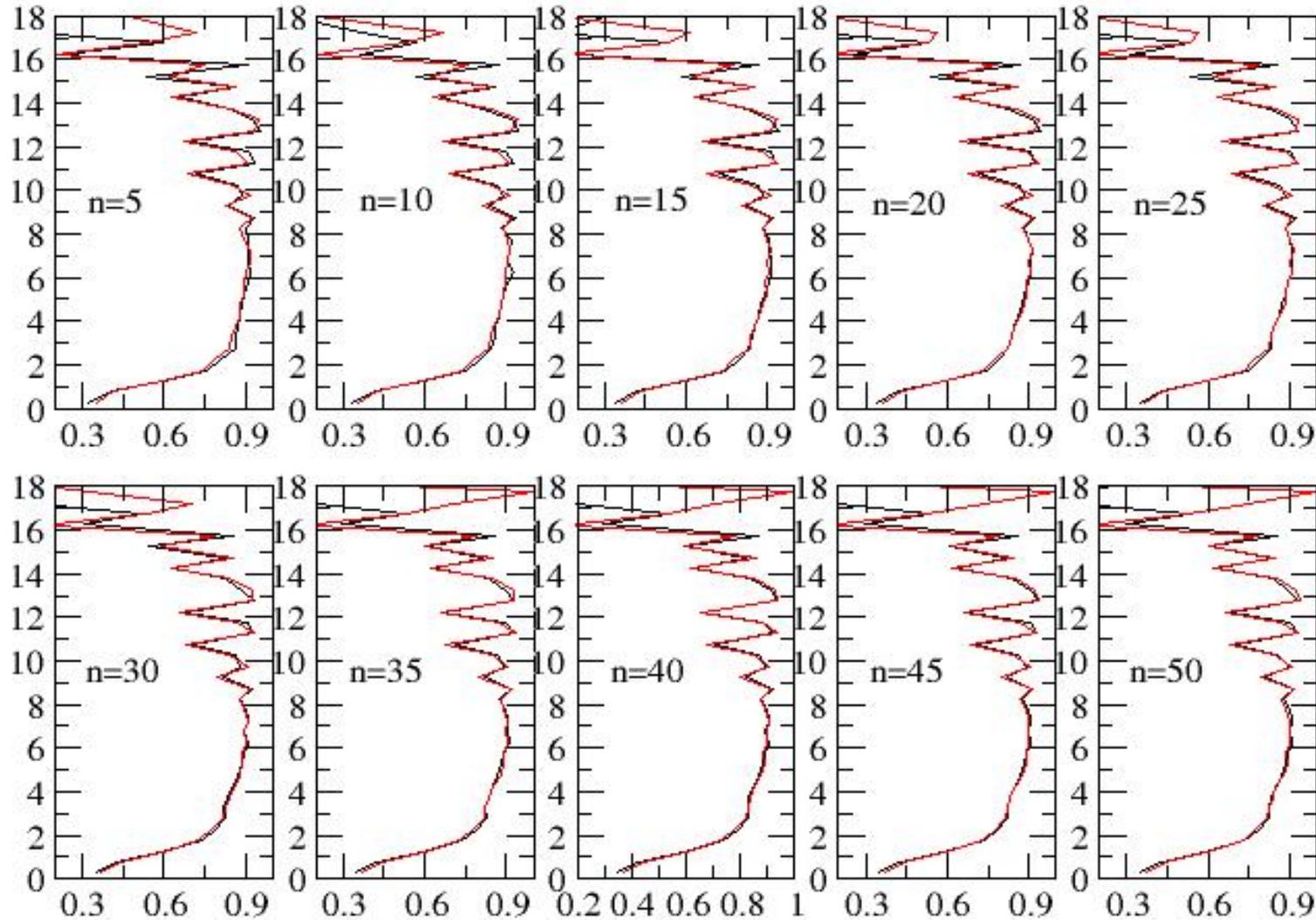


April 2013, Day Time, Ice-Free Ocean

— Without 3D — With 3D



Eff Cloud Height (km)



- Agree well for all n's, for altitude < 16 km

Cloud Fraction

$z > 16$ km, agree to some degree for $n < 30$, disagreement increases with increasing n

Cloud Fraction Comparison (with-3D and without-3D) as a function of cloud altitude

	Day Time	Night Time
Ocean (Ice-Free)	<ul style="list-style-type: none"> • $z < 16$ km, agree well for all n's • $z > 16$ km, agree to some degree for $n < 30$, disagreement increases with increasing n 	<ul style="list-style-type: none"> • Similar as for day time
Land (Snow-Free)	<ul style="list-style-type: none"> • $3 < z < 6$ km, 3D slightly under detected clouds for all n's (1-2%) • $z > 16$ km, somewhat over detected (~1%) • rest of z, good agreement for all n's 	<ul style="list-style-type: none"> • $5 < z < 16$ km, disagree some what for all n's, less than 1%, under detected • $z < 5$ km, good agreement for all n's • $z > 16$ km, agree well for $n < 30$
Snow-Ice Covered Sfc	<ul style="list-style-type: none"> • $z < 4$ & $z > 14$ km, agree well for ~ all n's • $4 < z < 14$ km, small disagreement for ~ all n's, almost no bias 	<ul style="list-style-type: none"> • $z < 13$ km, agree well for all n's, • $z > 13$ km, large disagreements occur for all n's.



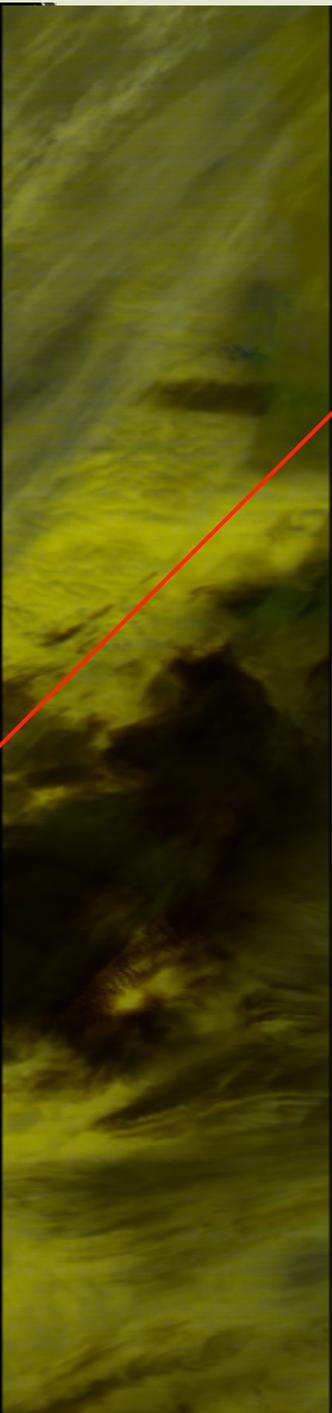
2013 04 02
00Z 55 min

Night Time
snow

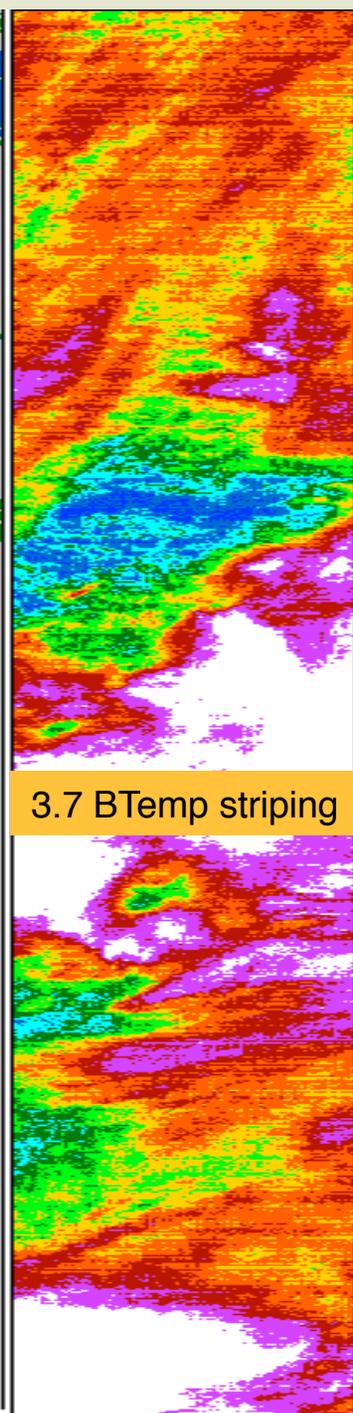
3.7 μm
BTemp
striping -->
striping in
cloud mask



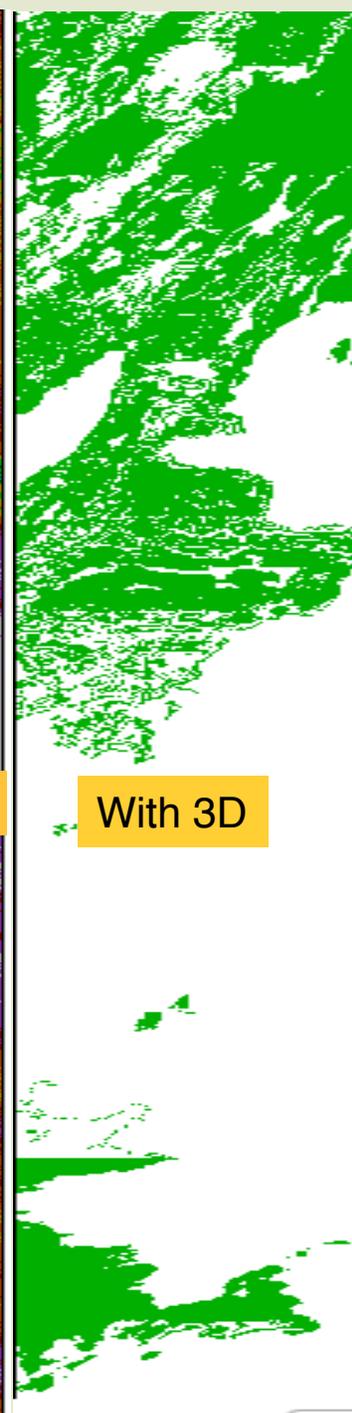
wat ice noRet



Without 3D



3.7 BTemp striping



With 3D

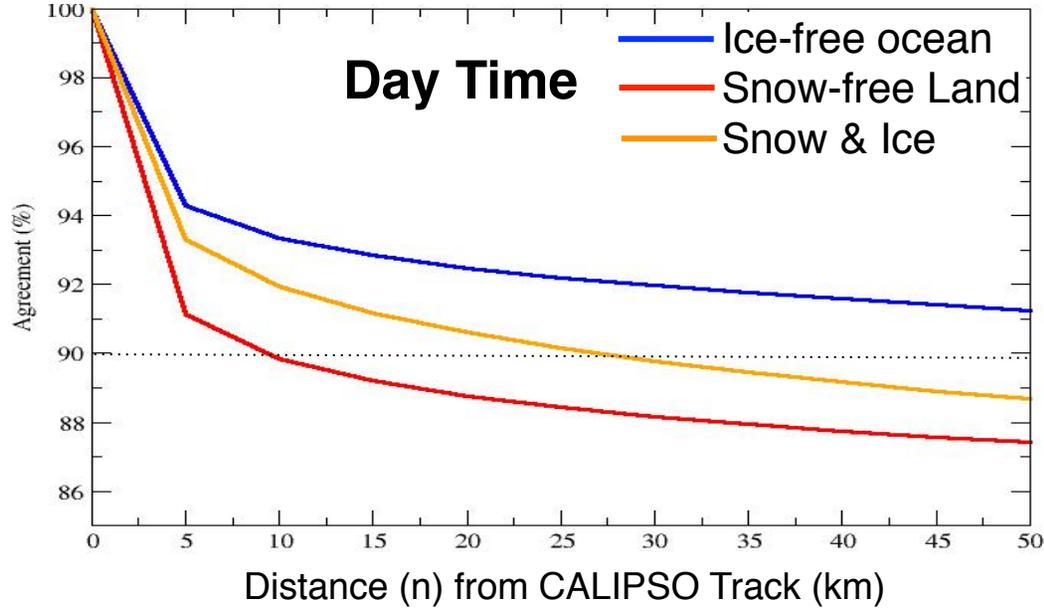
- Night time 3D does not use 3.7 μm .
- 3D clouds are more correct than without 3D



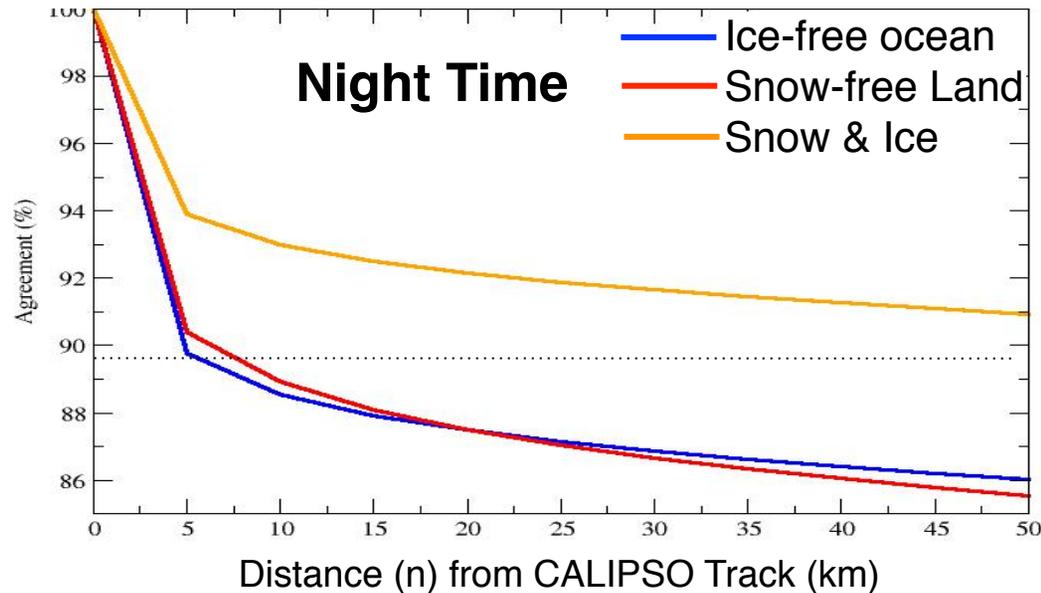
3D Cloud Property Assessment



Cloud Phase Agreement between 3D and without 3D



Cloud Phase Agreement between 3D and without 3D



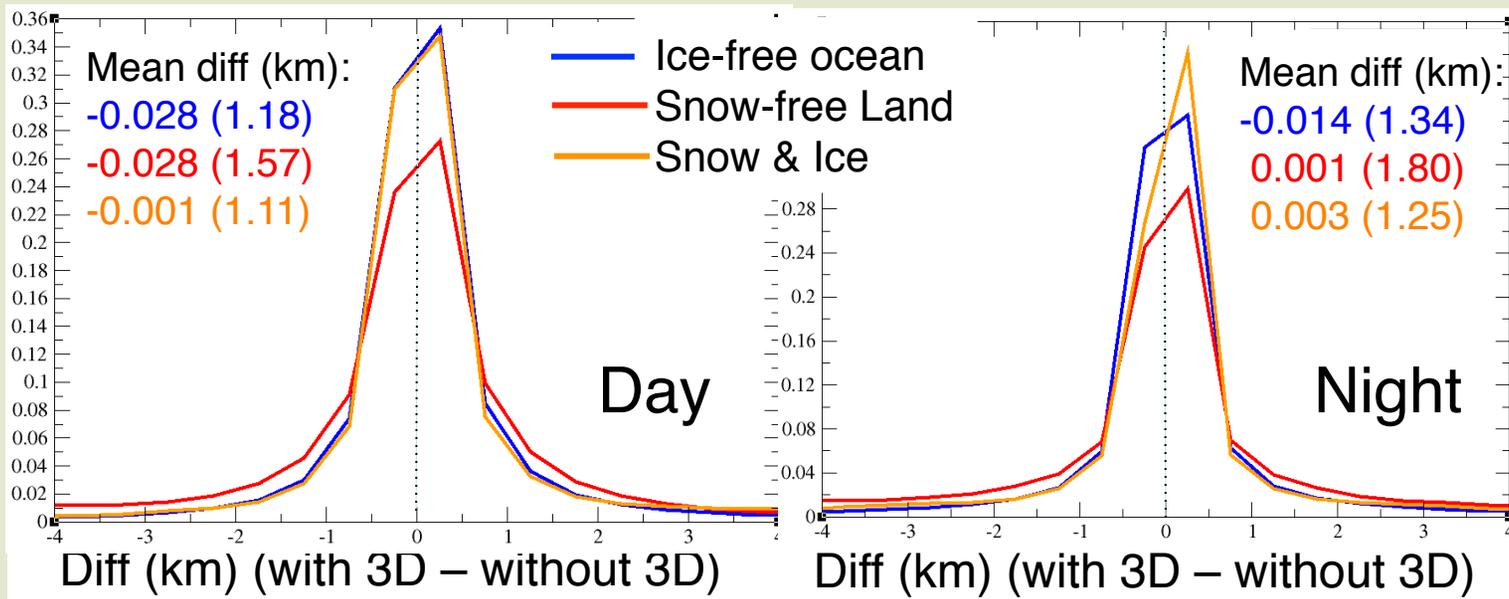
Cloud Phase Agreement between with-3D and without-3D, as a function of n (distance from track)

Cloud Phase:

- Day time agreement $> 87\%$ for all n's for both snow free and snow ice covered scenes.
- Night time over snow-ice, agreement $> 91\%$ for $n=50$, $\sim 86\%$ for snow-free surfaces



Histogram of Eff Cloud Height Diff (with-3D – without-3D)

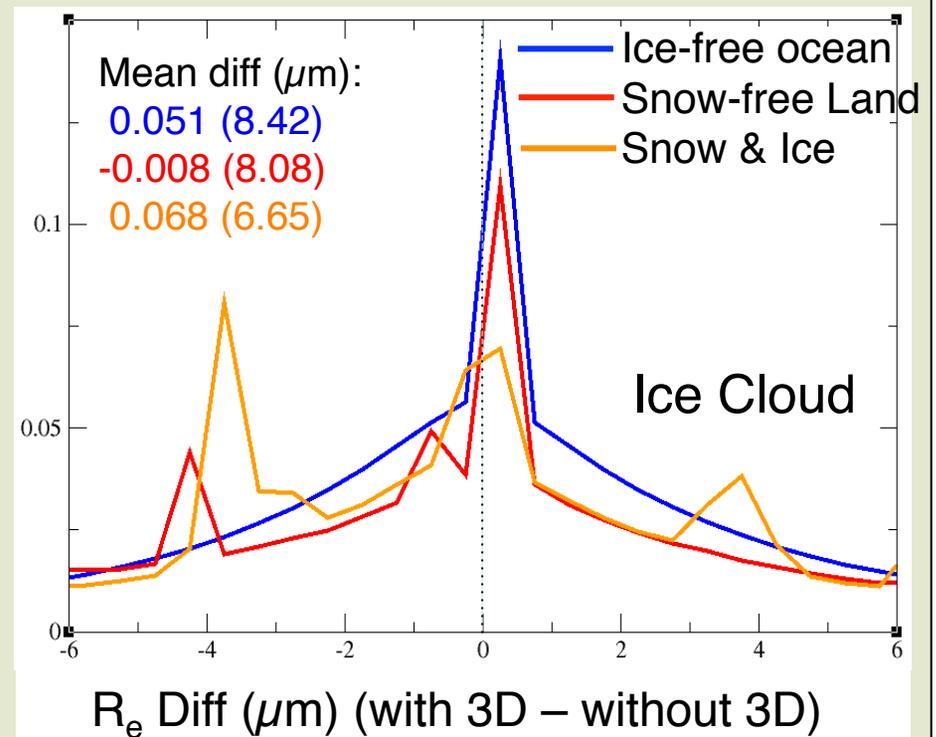
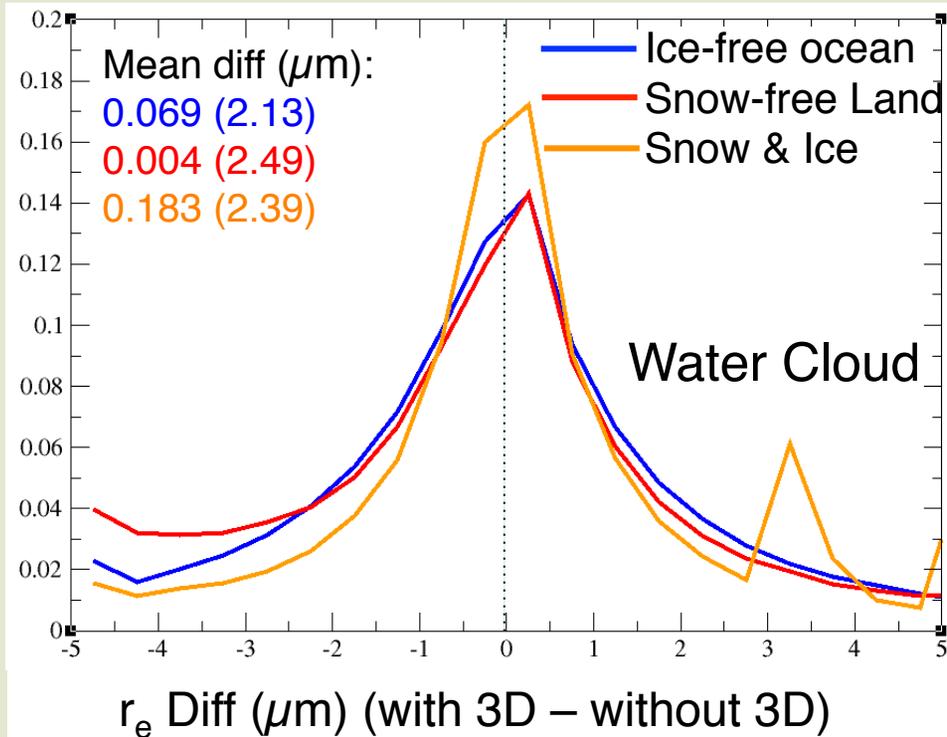


No bias between with 3D and
without 3D



Day Time

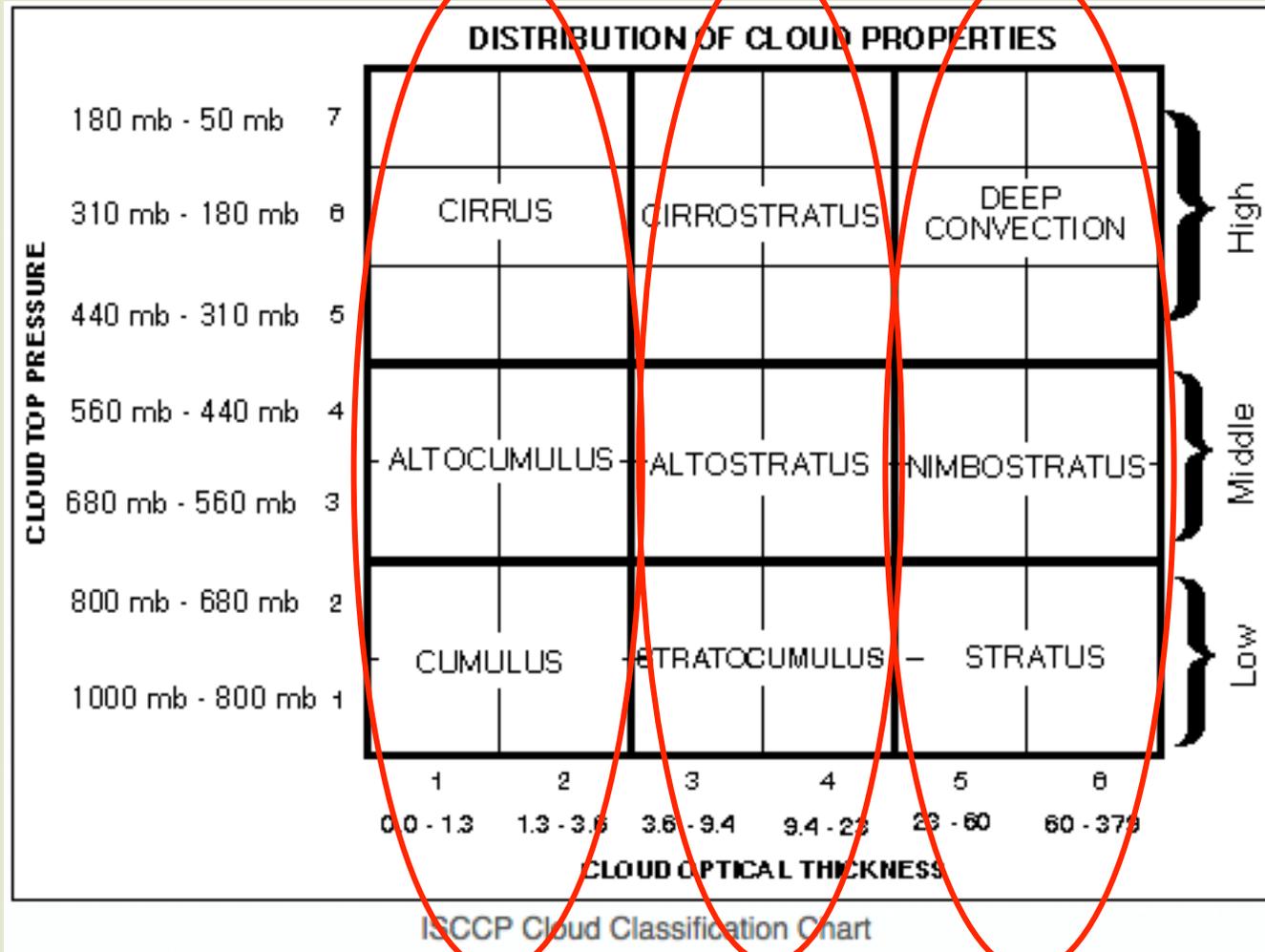
Histogram of Particle Size Difference (with-3D – without-3D)



- No bias in water radius between 3D clouds and without-3D clouds
- Bump in water radius at diff $\sim 3.3 \mu\text{m}$ over snow-ice ?

- Not much bias in ice radius over ocean
- A little questionable over land, 2 bumps, 3D R_e smaller
- Wide spread in Ice radius diff over snow-ice surfaces



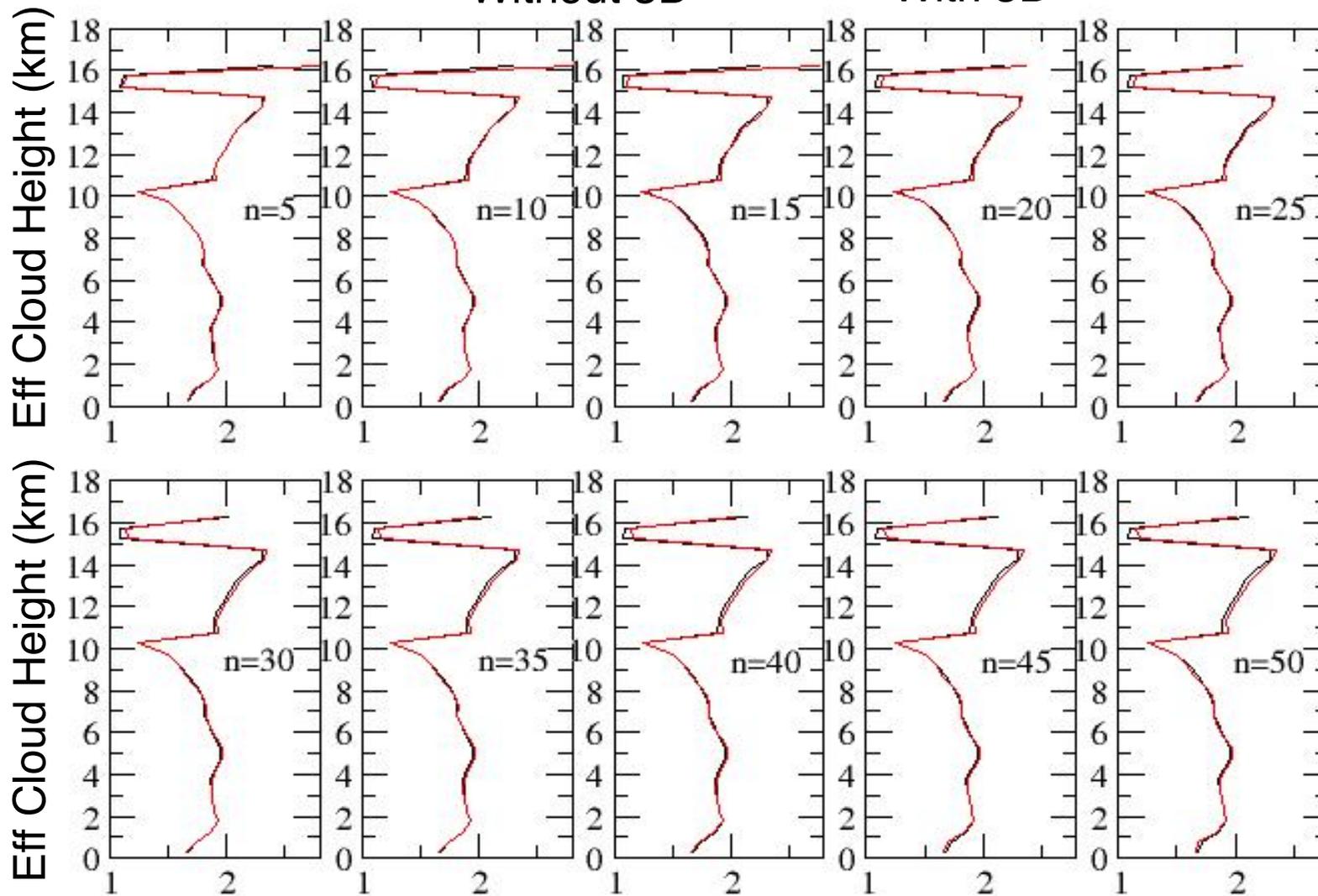


ISCCP regions 1: **Thin Optical Depth 0 --- 3.6**
 2: **Medium Optical Depth 3.6 --- 23**
 3: **Thick Optical Depth 23 --- 150**



April 2013, Day Time, Ice-Free Ocean, COD: 0 – 3.6

— Without 3D — With 3D



- Excellent agreement for all n's, at almost all altitudes

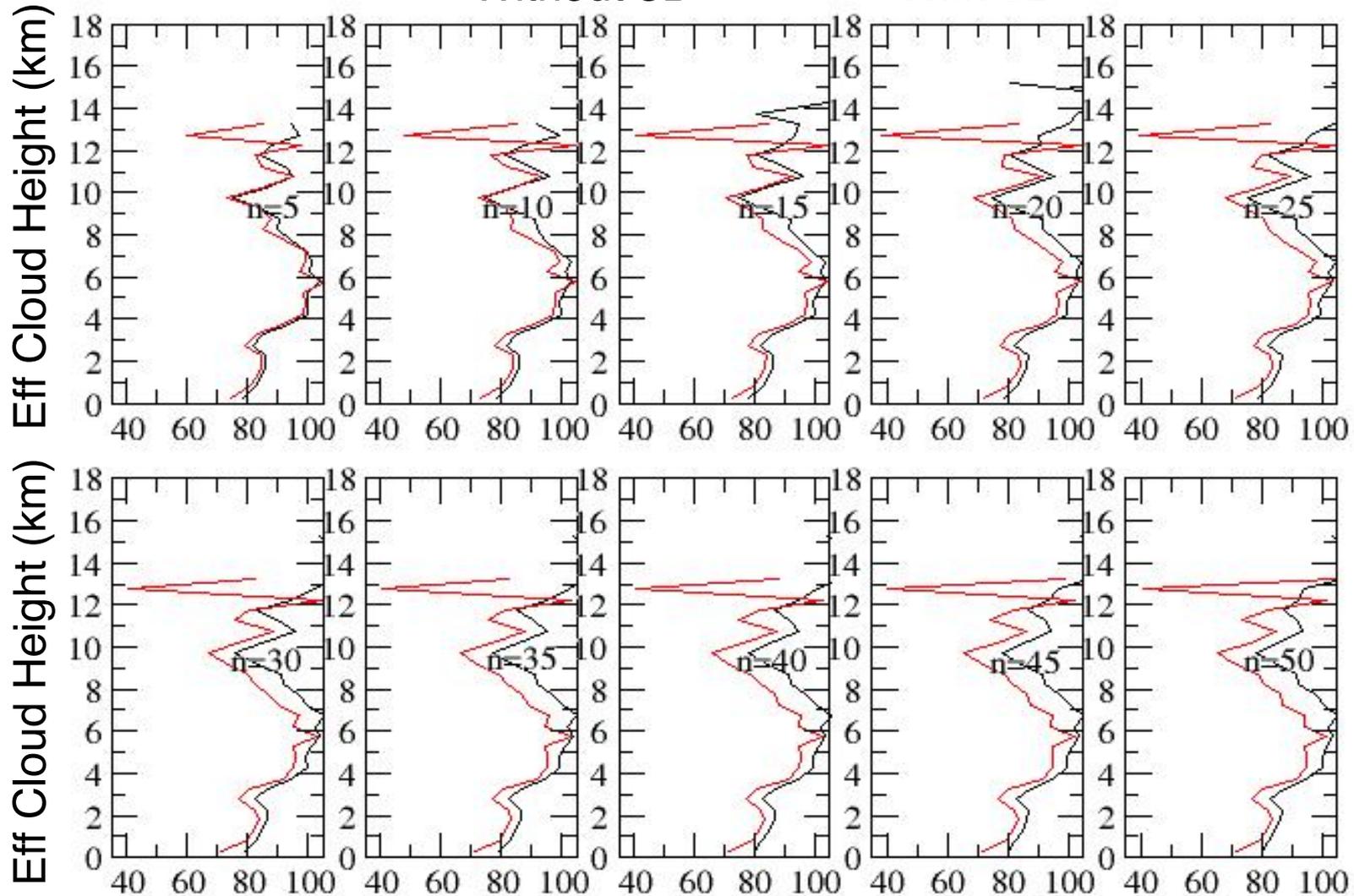
Optical Depth

Cloud Optical Depth Comparison (with-3D and without-3D) as a function of cloud altitude

	Thin COT < 3.6	Medium COT 3.6 – 23	Thick COT 23 -- 150
Ocean (Ice-Free)	<ul style="list-style-type: none"> Excellent agreement for all n's, at almost all altitudes 	<ul style="list-style-type: none"> Excellent agreement for all n's, at almost all altitudes 	<ul style="list-style-type: none"> Excellent agreement for all n's, at almost all altitudes
Land (Snow-Free)	<ul style="list-style-type: none"> z < 16 km, excellent agreement for all n's, at almost all z For z > 16 km, disagreements occur for all n's, worse as n increases, 3D being a slightly thicker 	<ul style="list-style-type: none"> Excellent agreement for all n's, at almost all altitude 	<ul style="list-style-type: none"> Excellent agreement for all n's, at almost all altitudes
Snow-Ice Covered Sfc	<ul style="list-style-type: none"> z < 13 km, excellent agreement z > 13 km, a constant COT difference, ~0.3, for all n's, 3D being thinner by ~ 0.3. 	<ul style="list-style-type: none"> z < 13 km, excellent agreement z > 13 km, good agreements for n < 20. Disagreement increases as increasing n (n > 20), 3D thinner by ~ 1-2 	<ul style="list-style-type: none"> 3D clouds thinner at all altitudes for all n's. 3D being thinner by 2 - 10 z > 12 km, large disagreements occur for all n's, much thinner. 3D being much thinner

April 2013, **Day Time, Snow / Ice Covered**, COD: 23 – 150

— Without 3D — With 3D



Optical Depth

**3D (red) thinner for all z and all n
much thinner for $z < 12$ km**

Summary

Overall, 3D Cloud Field Algorithm (Barker et al. 2011) works quite well. The agreement of cloud properties (mask, COT, height, sizes) between 3D cloud field and MODIS cloud is very good globally (~ the same as that between CALIPSO and MODIS).

1. Overall , $n = 30$ is probably a safe choice. C3M pixel level data will have $n = 50$. Users can choose their own n .
2. For ice clouds during night time over snow-ice ($z > 12$ km), 3D cloud mask has completely different clouds compared with CERES-MODIS clouds. Might not be 3D issue \rightarrow likely caused by $3.7 \mu\text{m}$ striping used in CERES-MODIS cloud mask.
3. Cloud mask, phase, optical depth and height compare well. Overall 3D clouds over snow-ice are thinner \rightarrow could it caused by CERES-MODIS uses $1.24 \mu\text{m}$ for optical depth over snow and ice, which is larger than visible optical depth?

