THE NEWLY OPERATIONAL VIIRS CLOUD BASE AND CCL (CLOUD COVER/LAYERS)

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with
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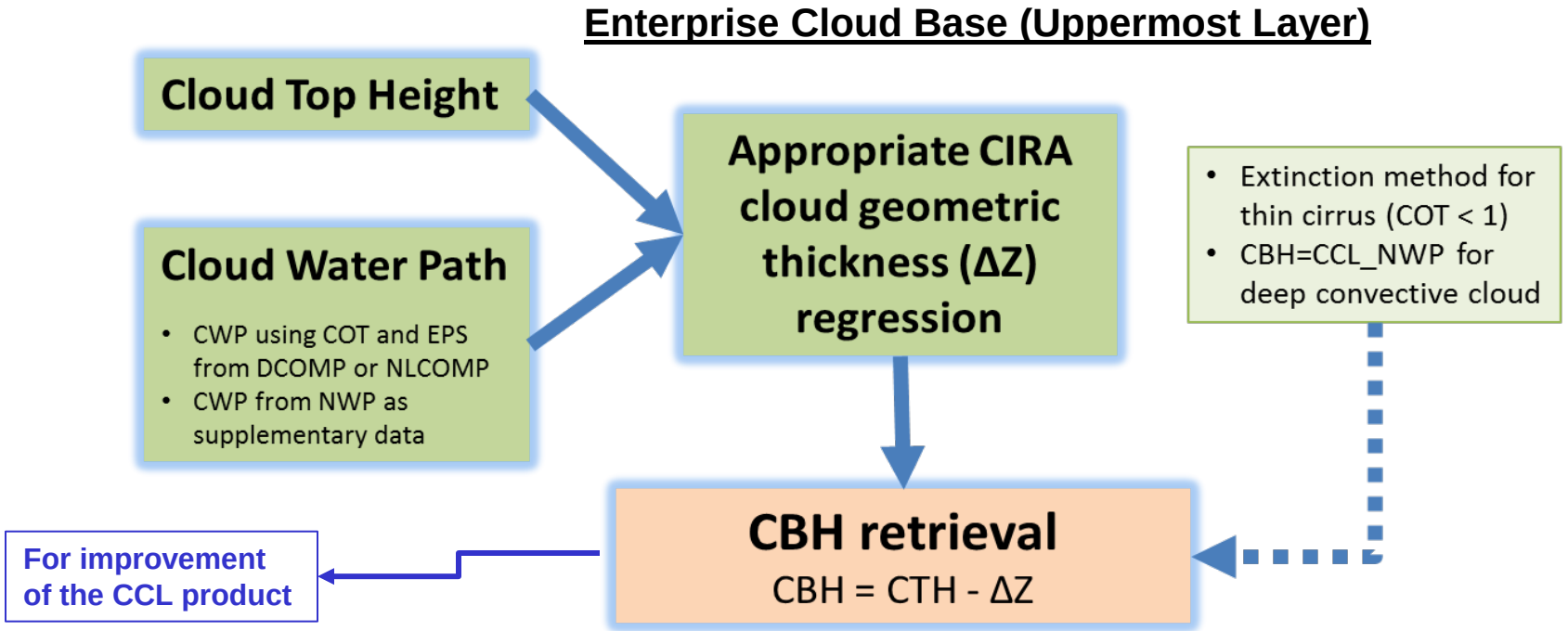
Introduction

- Knowledge of Cloud Base Height (CBH) is critical to describing cloud radiative feedbacks in numerical models and is of practical significance to aviation communities.
- We developed a new CBH algorithm constrained by Cloud Top Height (CTH) and Cloud Water Path (CWP) using a statistical analysis of A-Train satellite data. It includes an extinction-based method for thin cirrus.
- The cloud base information is a key parameter for an improved Cloud Cover/Layers (CCL) product for lower clouds.
- The CBH product has been applied to Suomi-NPP VIIRS and intensively evaluated against CloudSat data. The results showed the new algorithm yields significantly improved performance over the original VIIRS IDPS CBH algorithm.

Enterprise CBH Algorithm



- The first version of the CBH algorithm and ATBD was delivered to the STAR Algorithm Implementation Team in February 2016. The CIRA and CIMSS team is now evaluating the operational test output.

✓ Seaman, C. J., Y. J. Noh, S. D. Miller, A. K. Heidinger, and D. T. Lindsey, 2016: Cloud Base Height Estimation from VIIRS. Part I: Operational algorithm validation against CloudSat. *J. Atmos. Ocean. Tech., submitted.*

✓ Noh, Y. J., J. M. Forsythe, S. D. Miller, C. J. Seaman, Y. Li, A. K. Heidinger, D. T. Lindsey, M. Rogers, and P. Partain, 2016: Cloud Base Height Estimation from VIIRS. Part II: Development of a statistical cloud base height retrieval algorithm using A-Train satellite data. *J. Atmos. Ocean. Tech., submitted.*

Product Overview and Status

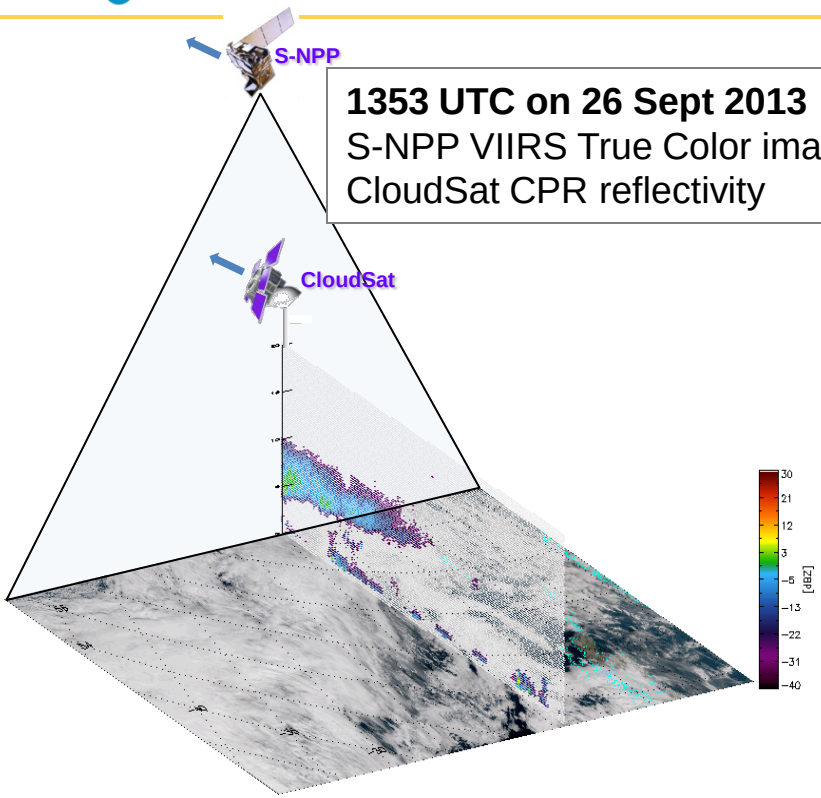
- Performance Summary

Product	L1RDS Specification	Bias Estimate (mean)	Standard Deviation Estimate
CBH	2 km	0.4 km	1.6 km

(from 5-month matchup comparisons between VIIRS CBH and CloudSat observations)

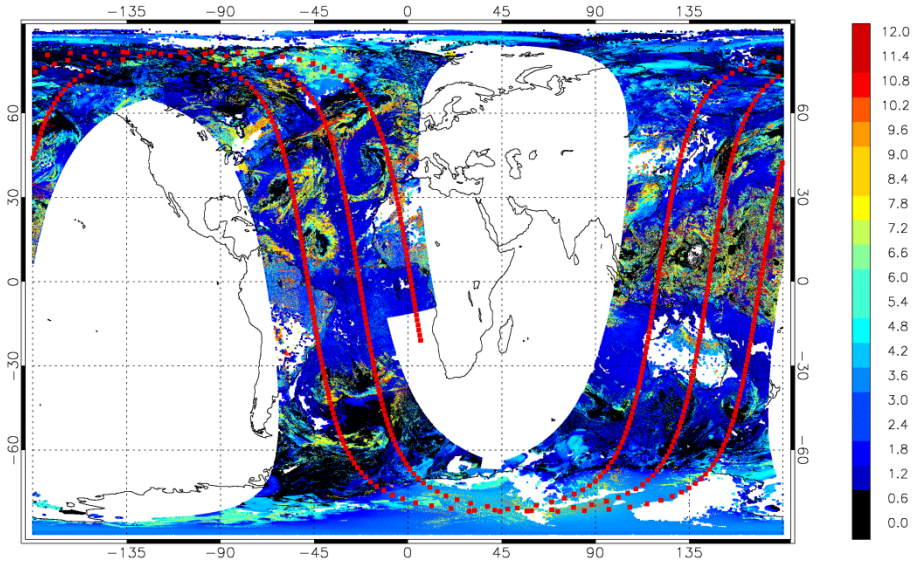
- The Enterprise CBH algorithm code has been delivered to the STAR Algorithm Implementation Team, now being tested in the operational frame.
- <u>New work in progress</u>
  - ✓ Combine CloudSat and CALIPSO for more robust validation.
  - ✓ Assess the nighttime performance using ground-based measurements.
  - ✓ Improve CCL products using the cloud base information.
  - ✓ Additional algorithm refinements: adopt an adiabatic model for low marine boundary layer clouds.

Matching VIIRS with CloudSat



1353 UTC on 26 Sept 2013
S-NPP VIIRS True Color image
CloudSat CPR reflectivity

VIIRS CBH [km] with A-Train overpass track
from 1334-1812 UTC on 26 Sept 2013

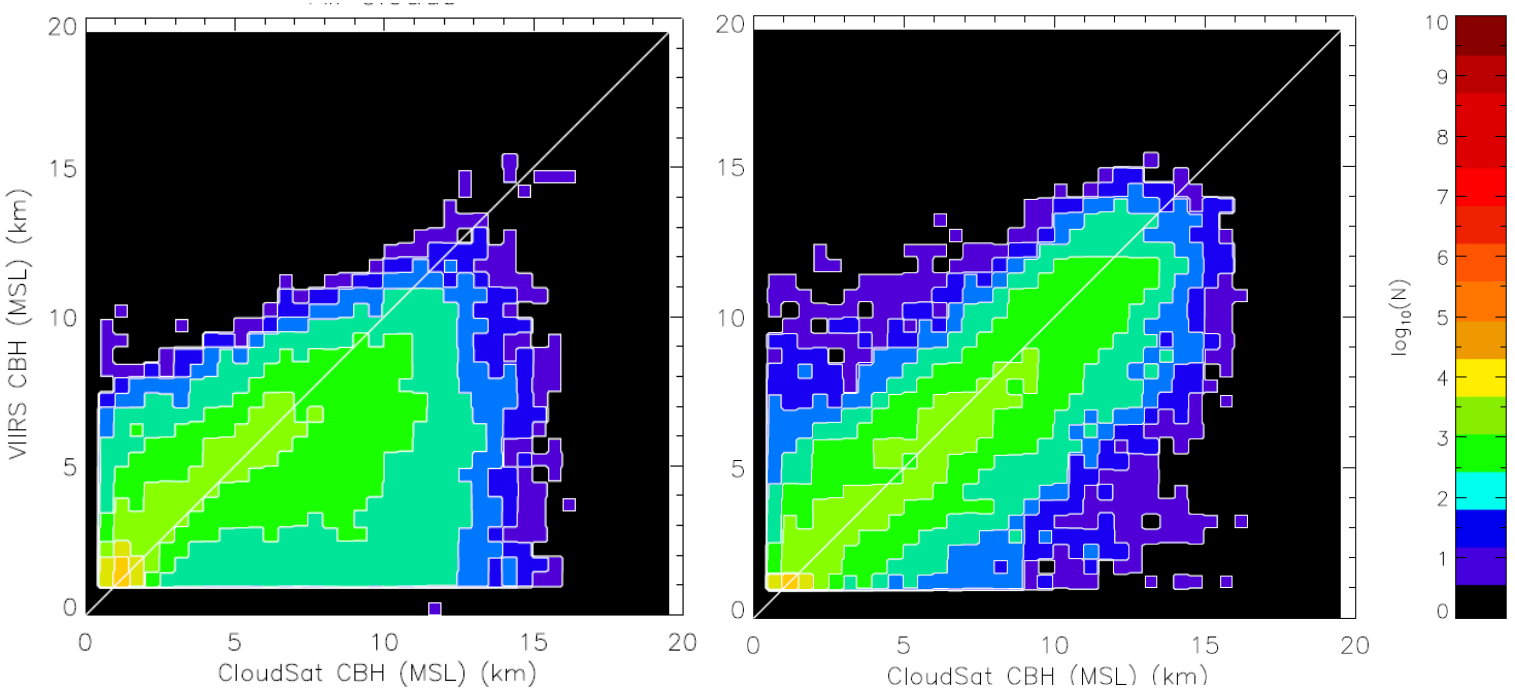


- The CBH product has been applied to Suomi-NPP VIIRS and intensively evaluated against CloudSat data.
- CloudSat-VIIRS overlap for ~4.5 hours every 2-3 days (8-9 matchups per month)
- Due to battery issues, CloudSat only operates on the **daytime** side of the Earth
- Use only the closest VIIRS pixels that overlap CloudSat and have CBH above 1 km

IDPS vs. Enterprise CBH: "Within Spec"

The enterprise CBH performs better.

The original IDPS with CLAVR-x input | **CIRA Statistical Regressions**

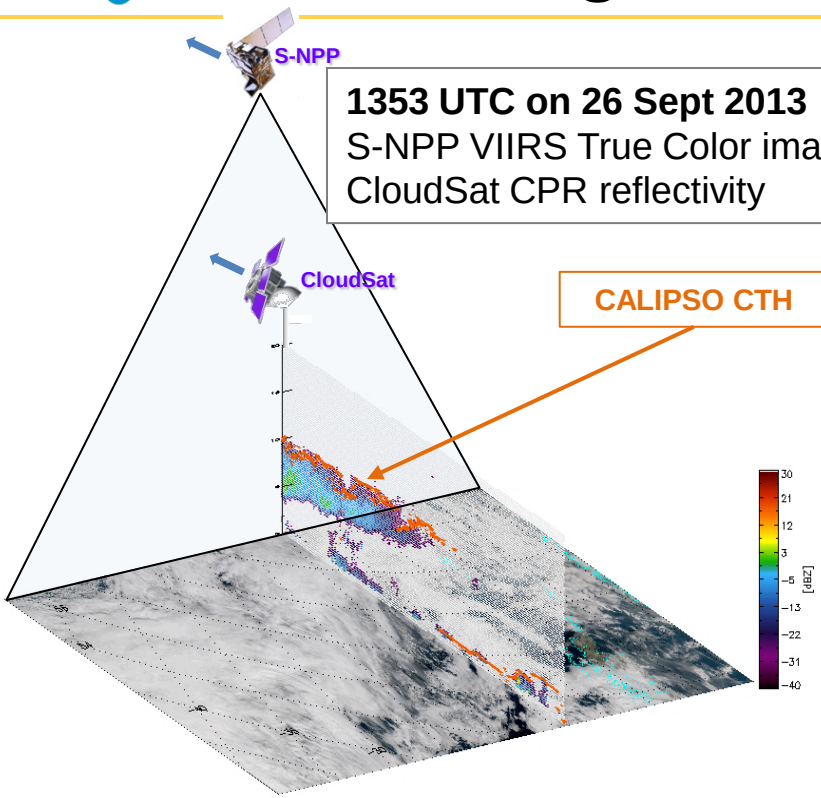


- "**Within Spec**" evaluation for only clouds where the VIIRS CTH retrieval is within the error specifications: CTH within 1 km of CloudSat CTH if COT ≥ 1, or within 2 km if COT < 1 (82599 matchup points for Sept-Oct 2013)

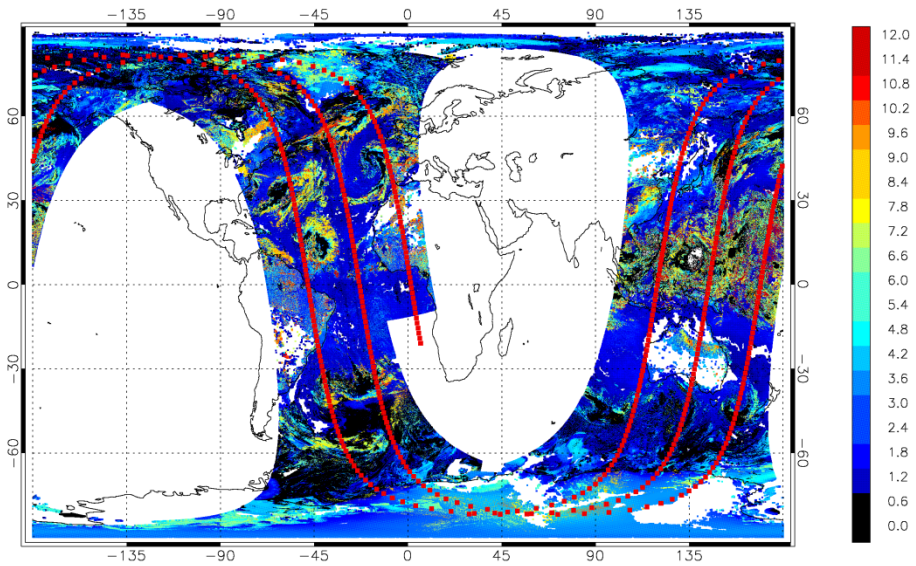
CBH [km]	Avg error (bias)	RMSE	Std of error	r^2
IDPS	0.7	2.7	2.6	0.45
Enterprise	0.3	1.8	1.8	0.76

✓ **Much better!**

Matching VIIRS with CloudSat and CALIPSO



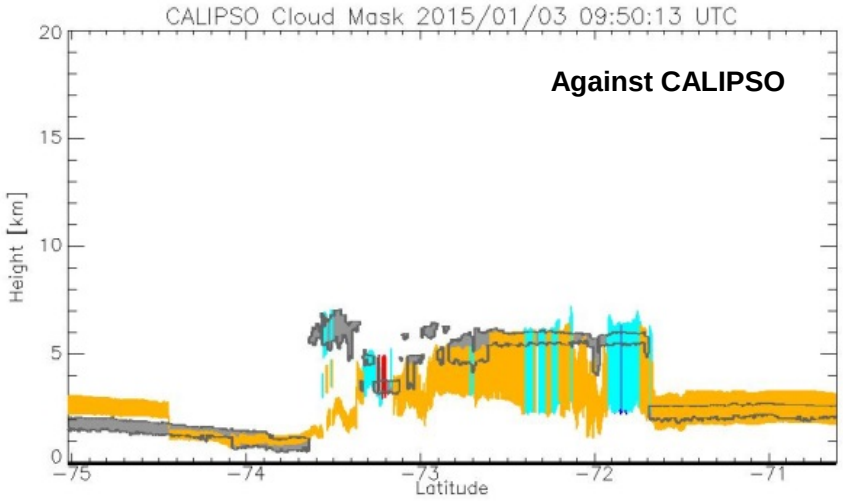
VIIRS CBH [km] with A-Train overpass track
from 1334-1812 UTC on 26 Sept 2013

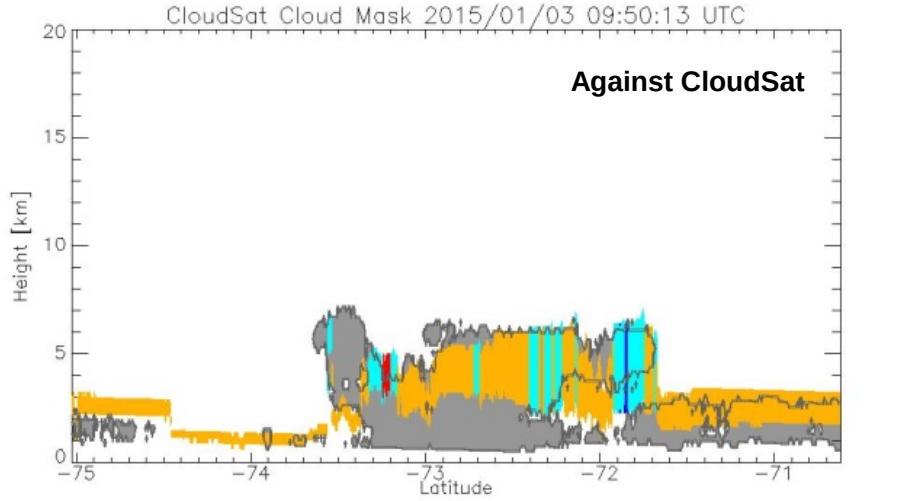


- CALIPSO data is added for validation of optically thin clouds and low water clouds that are often missed by CloudSat.
- The 2B-GEOPROF-LIDAR product is no longer available since the CloudSat battery anomaly in 2011, which made it difficult to maintain tight formation flying of CALIPSO and CloudSat, but they are still within the same orbit.
- CALIPSO Level2 1-km Cloud Layer product used for the matchup.

CBH Validation adding CALIPSO

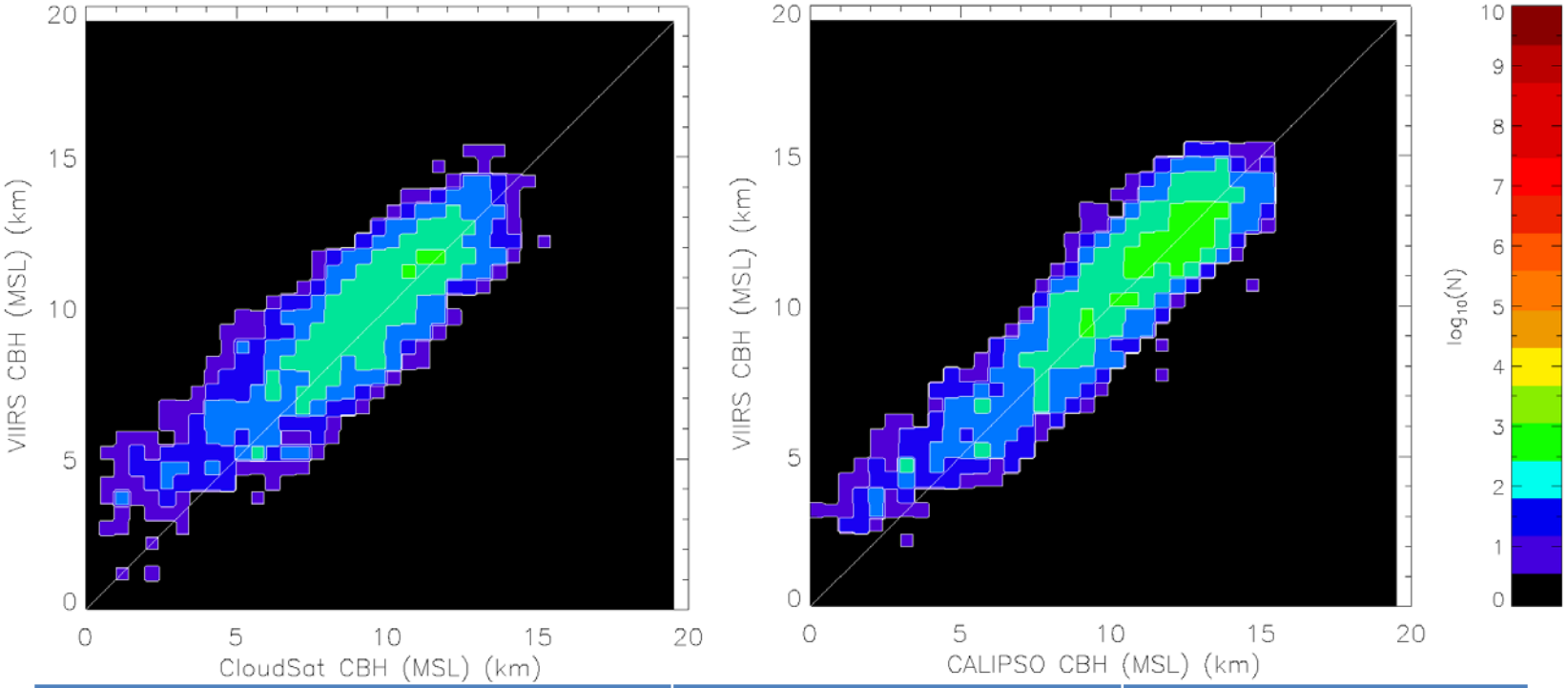
- Topmost layer CBH and CTH data are used for thin clouds (COT<1) and water clouds during Sep-Oct 2013 matchup period.
- **Cloud detection** greatly increases from 5518 to 8738 profiles (within spec) by CALIPSO for thin clouds and from 8730 to 40840 for low water clouds by combining CloudSat/CALIPSO.





Validation of Thin Clouds Using CALIPSO

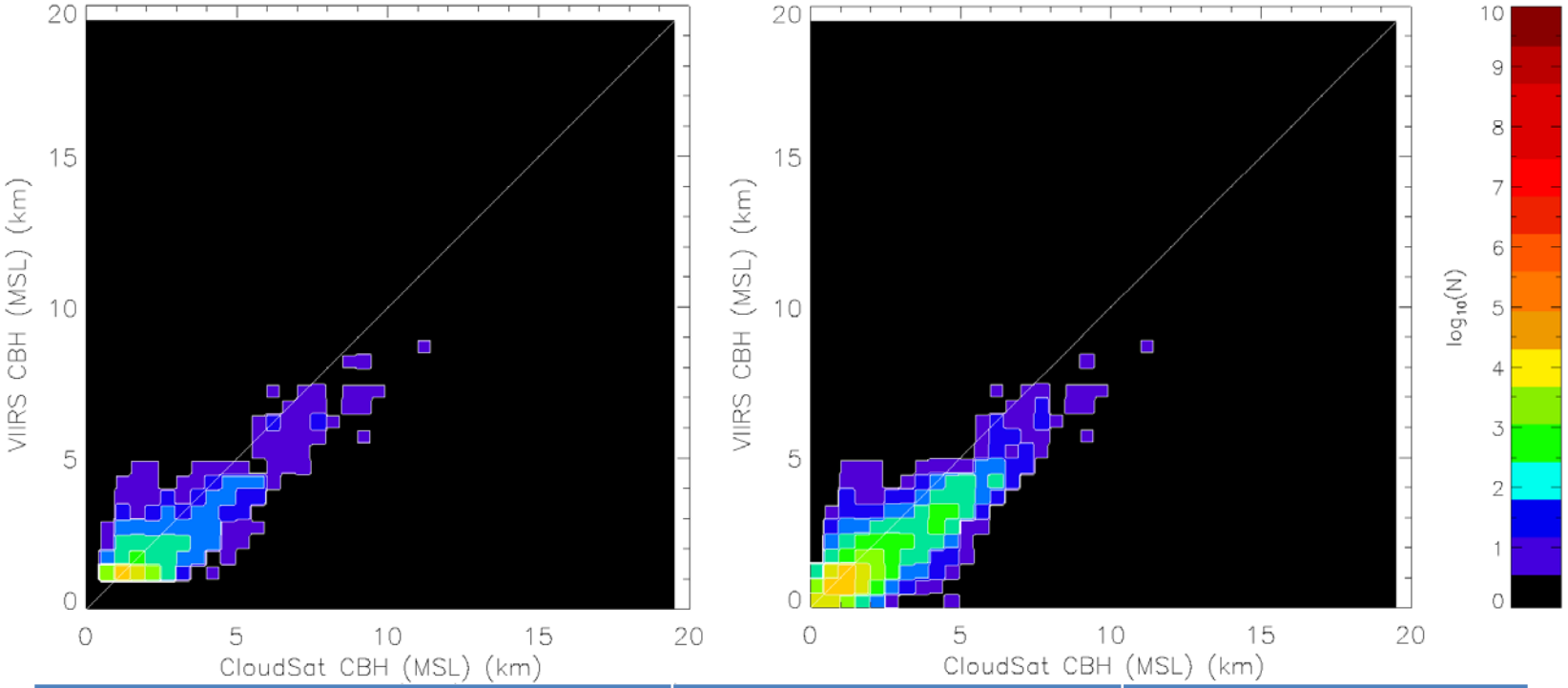
Thin clouds (COT < 1) “within spec” (CTH error < 1 km) using CloudSat (left) and CALIPSO (right)



Errors	CloudSat	CALIPSO
R^2	0.78	0.84
Average error (bias)	-0.5 km	-0.3 km
Standard deviation error	1.2 km	1.0 km
Median error	-0.5 km	-0.2 km
RMSE	1.3 km	1.1 km

Validation of Water Clouds Using CALIPSO/CloudSat

Water clouds “within spec” (CTH error < 1 km) using CloudSat (left) and Combination (right)

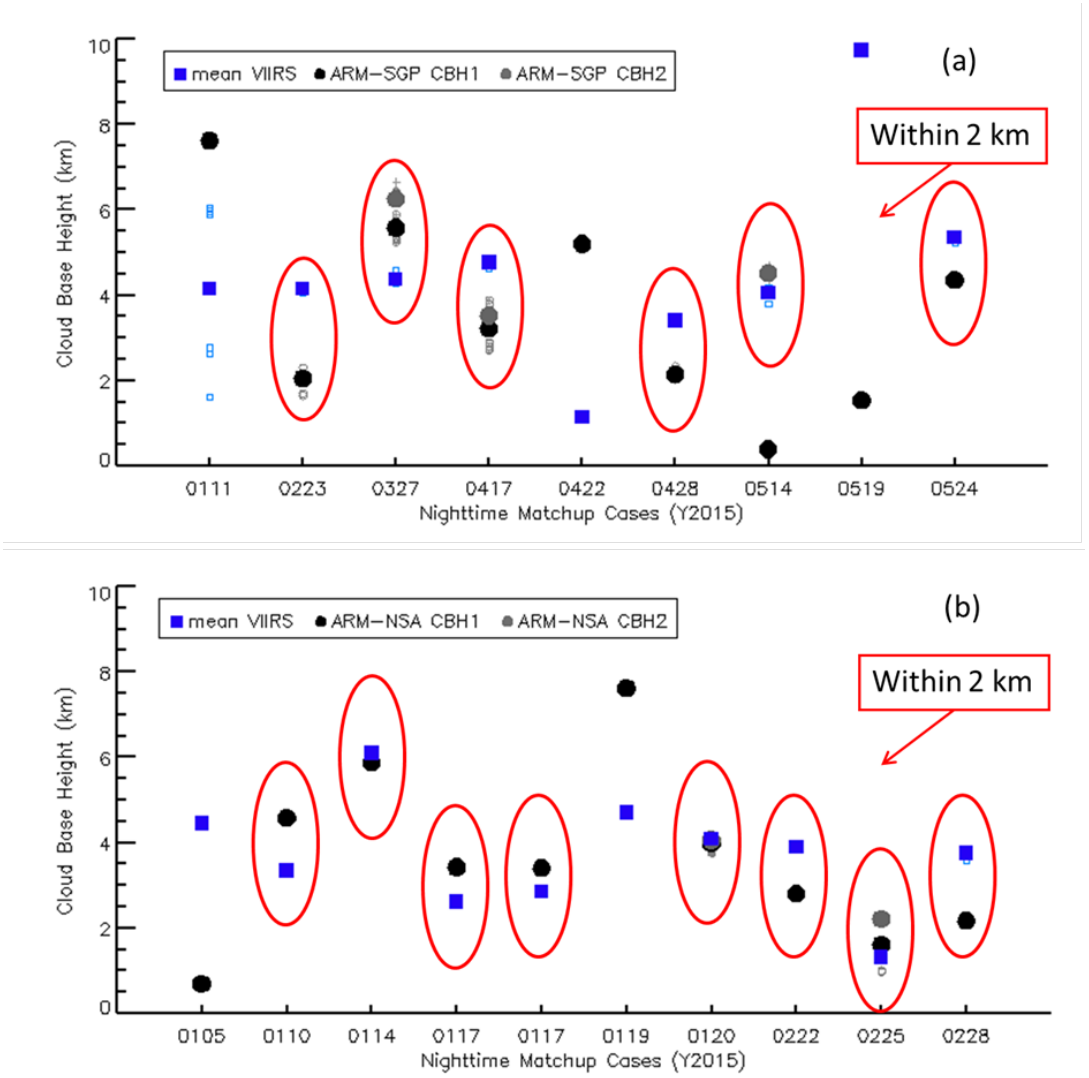


Errors	CloudSat	CloudSat/CALIPSO
R^2	0.80	0.83
Average error (bias)	0.2 km	0.1 km
Standard deviation error	0.4 km	0.4 km
Median error	0.2 km	0.1 km
RMSE	0.5 km	0.4 km

5 times more samples

Nighttime CBH algorithm performance

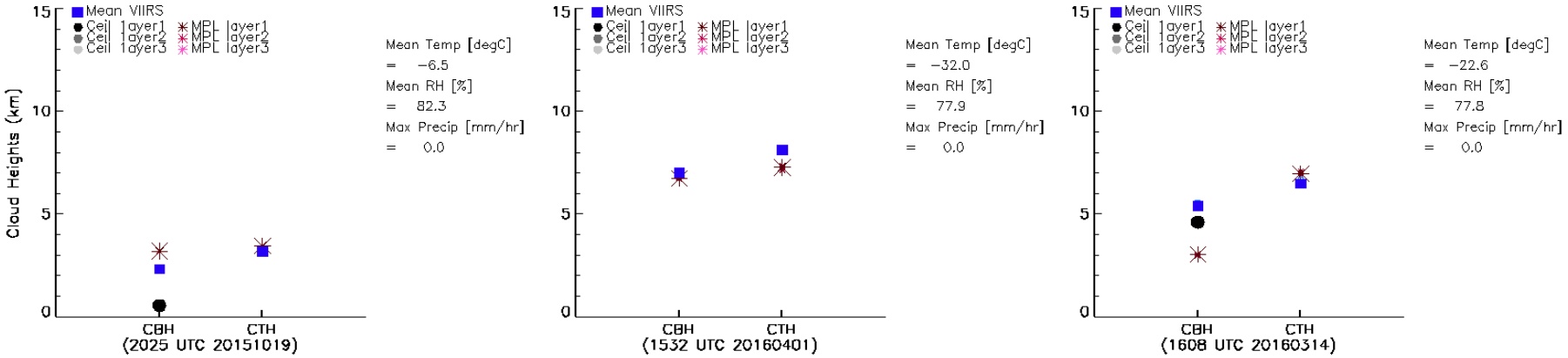
- CBH is retrieved in both day and **night**.
- Sample evaluations for nighttime CBH performance using ARM ceilometer data from SGP and NSA sites.
  - Blue squares: VIIRS CBHs
  - Black and gray circles: ARM ceilometer CBHs
- CBHs within the 2-km error range are circled in red.



Nighttime CBH algorithm performance

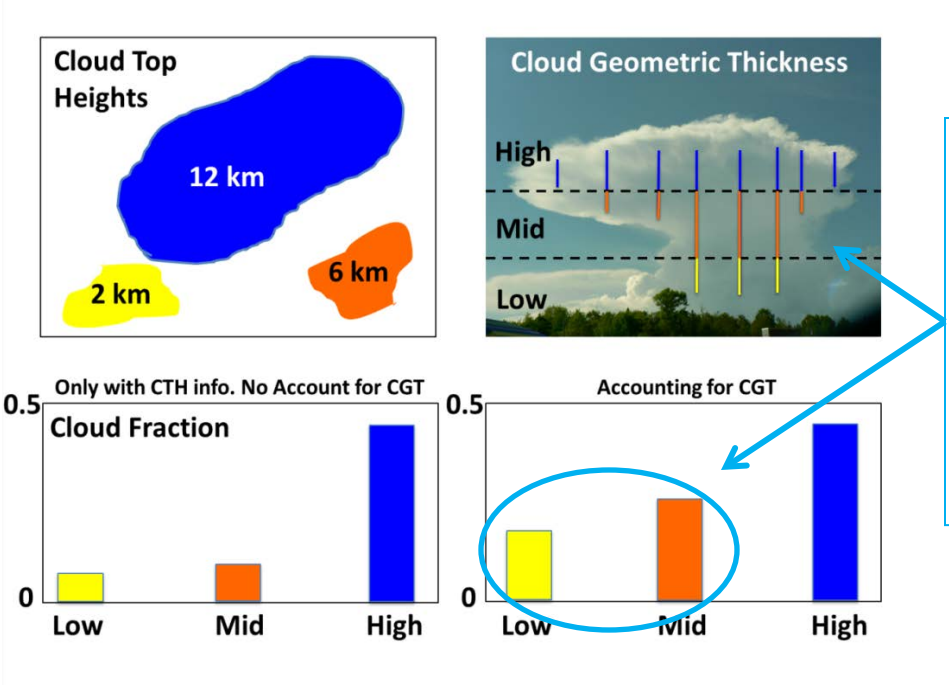
- Validation for an extended period
  - 581 matchups from October 2015 to April 2016
- Ground-based measurements from Ceilometer and Micropulse Lidar at the ARM site on the North Slope of Alaska
- CALIPSO data will be added for multi-layered cloud cases which may have high clouds aloft beyond the ground measurements.

Sample matchup cases from VIIRS-ARM data at night



For Improvement of CCL products

- The cloud base information is used for improvement of CCL products.
- The beta version is tested in the CLAVR-x system. The current CCL algorithm (part of ACHA by Andy Heidinger) is based on cloud top pressures over 3x3 pixels. The high and low layer thresholds are 440 hPa (~6.5 km) and 680 hPa (~3 - 3.5 km).
- The new sub-layer info is obtained by comparing the cloud base data and layer thresholds, and more fractions for lower cloud layers if present.

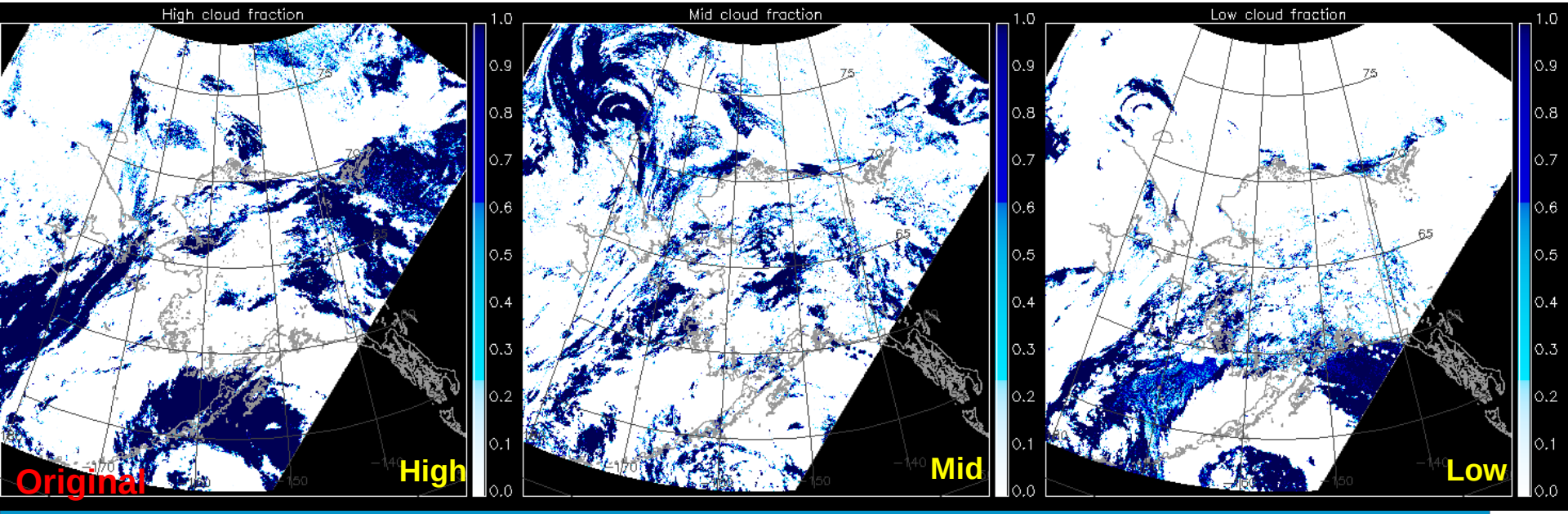


The CBH information can be used to modulate the layered cloud fraction (high/mid/low) by introducing additional cloud coverage at lower (unobserved via satellite) levels of the profile.

Improvement of VIIRS Cloud Cover/Layers

- The new cloud base information is employed to enhance lower cloud layer fractions often missed by the previous CCL retrieval.
- The improved CCL algorithm has been applied to VIIRS.
- Also applicable to geostationary satellite: Himawari-8 AHI for the future GOES-R ABI

S-NPP VIIRS 20160229 (1351-1401 UTC)



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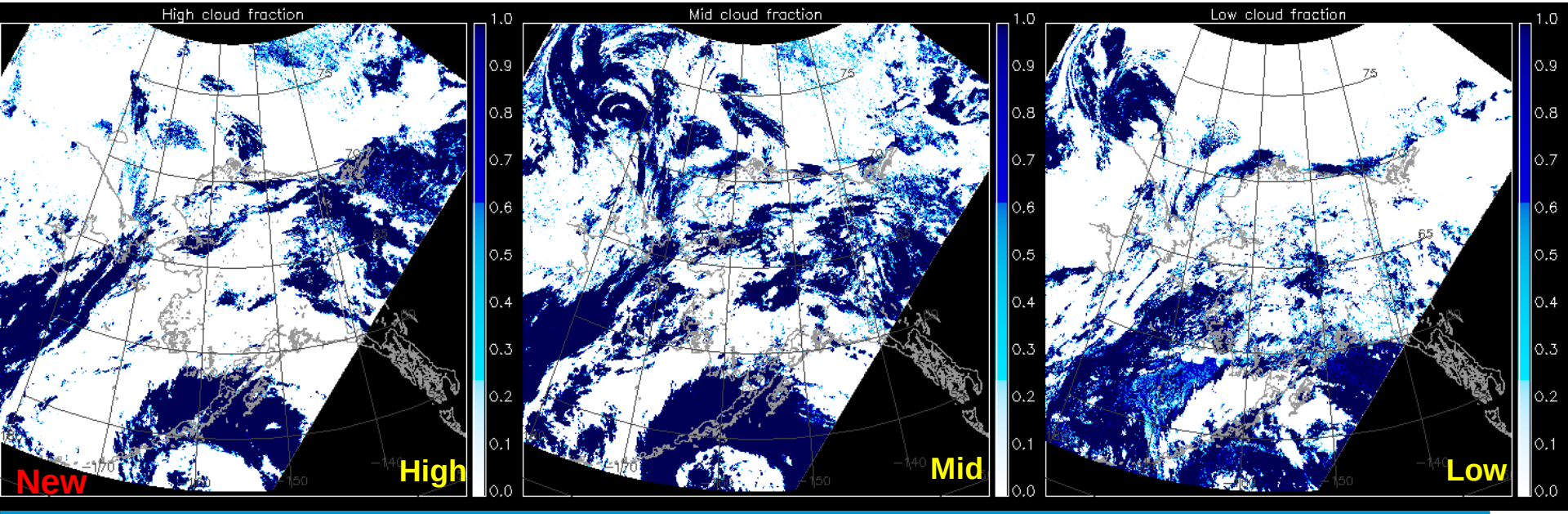
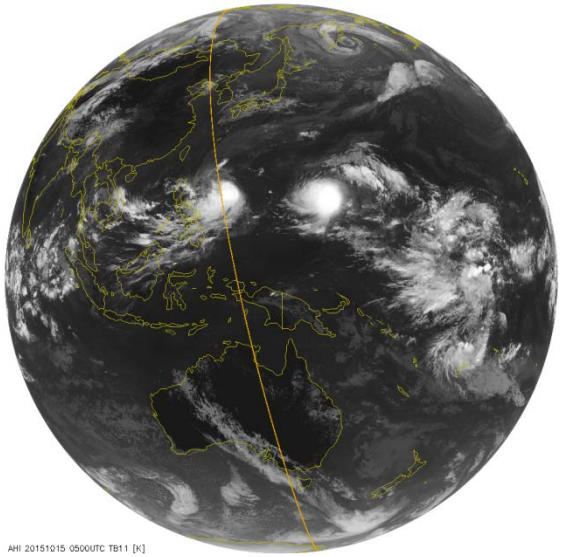


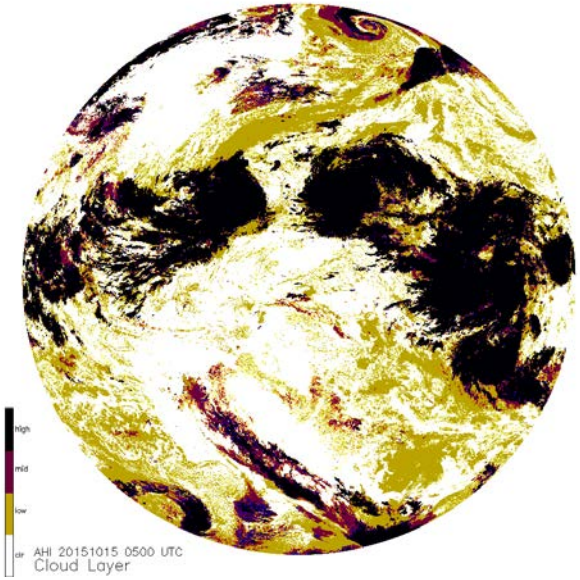
Himawari-8 AHI Cloud Cover/Layers

20151015 (0500 UTC)

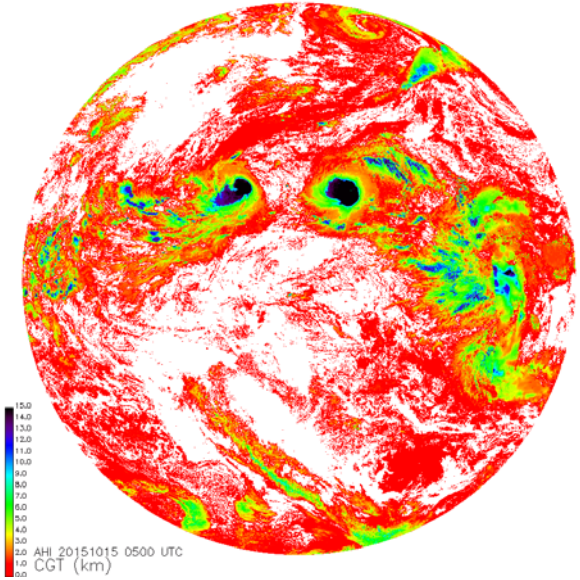
Himawari-8 AHI TB_11 μm



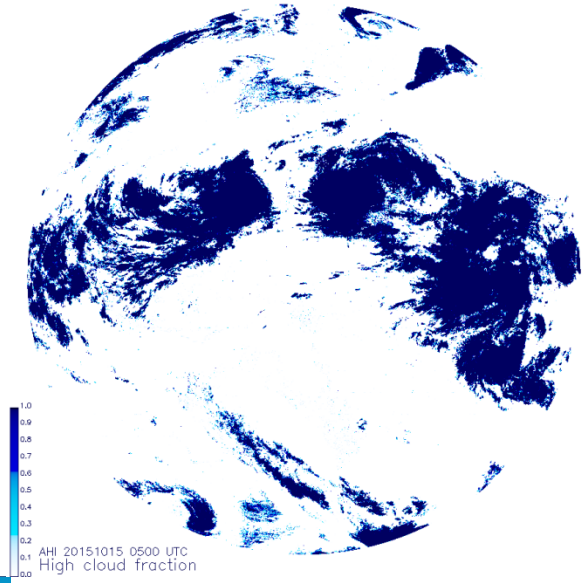
Cloud Layer



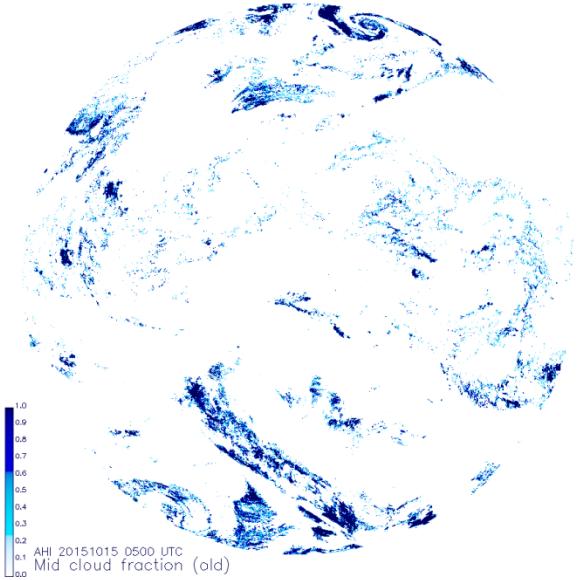
Cloud Geometric Thickness



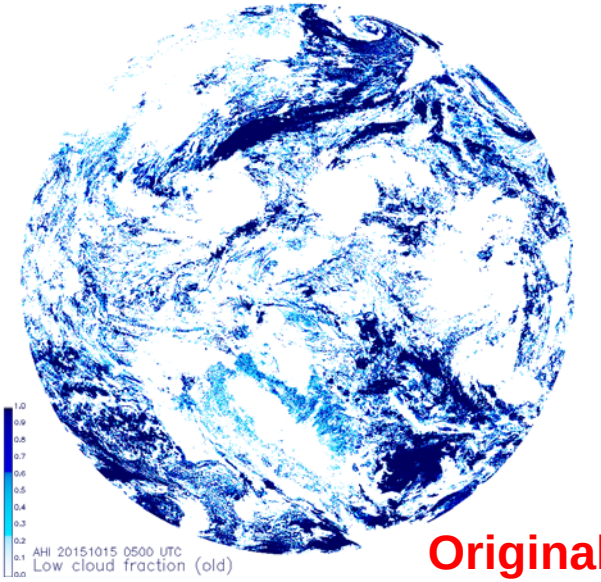
High Cloud Fraction



Mid Cloud Fraction



Low Cloud Fraction

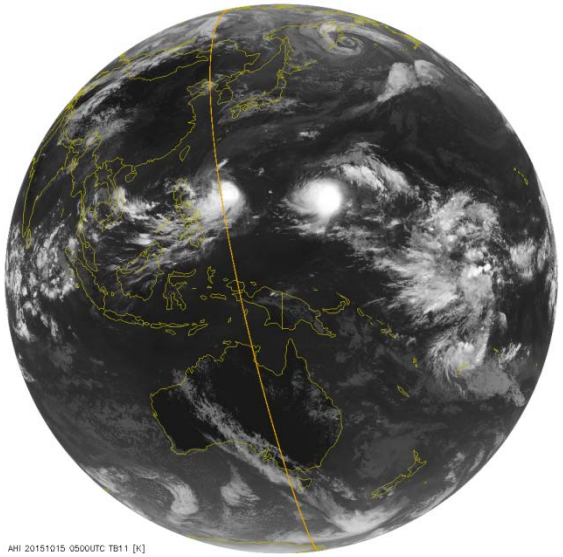


Original

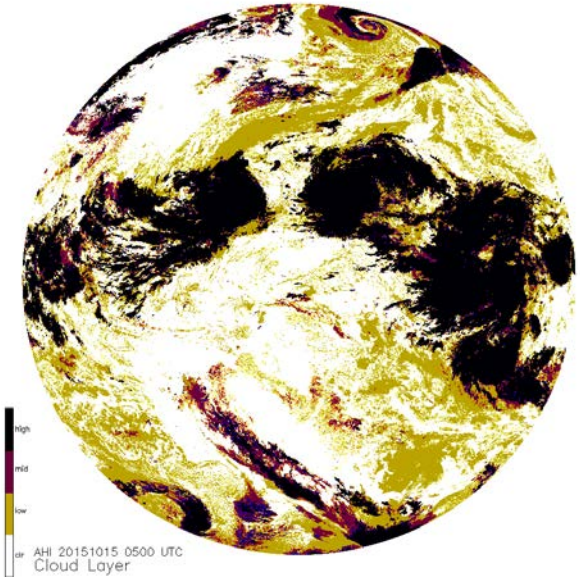
Himawari-8 AHI Cloud Cover/Layers

20151015 (0500 UTC)

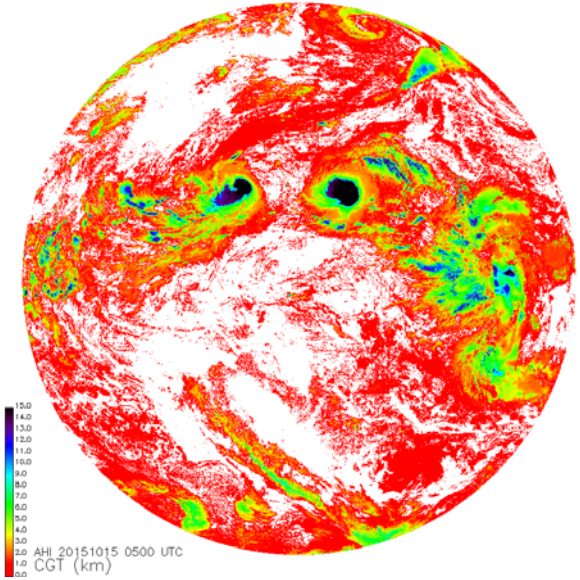
Himawari-8 AHI TB_11 μm



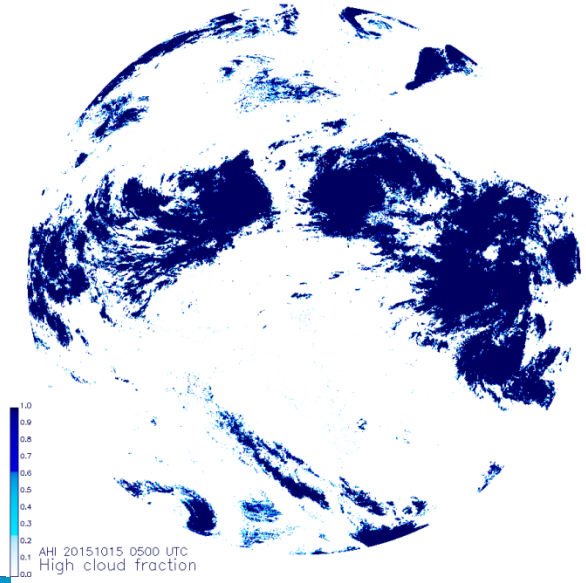
Cloud Layer



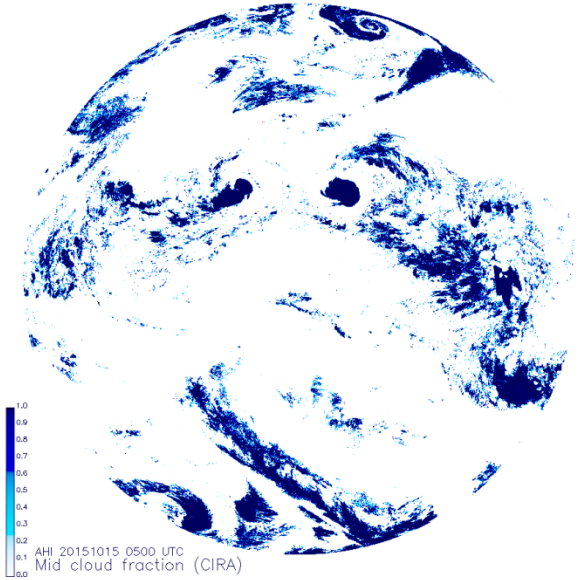
Cloud Geometric Thickness



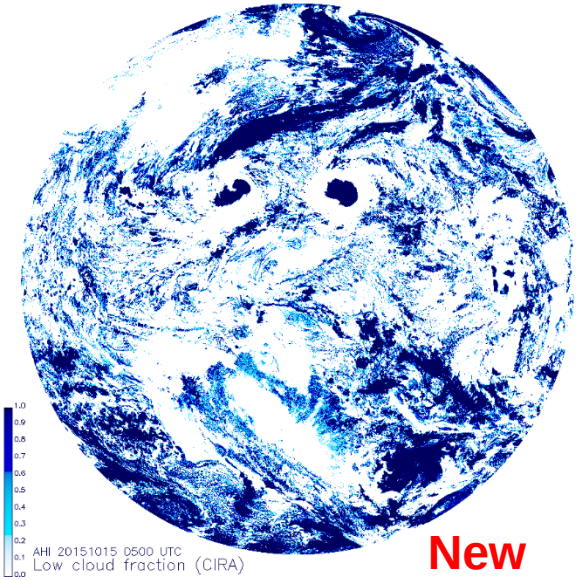
High Cloud Fraction



Mid Cloud Fraction



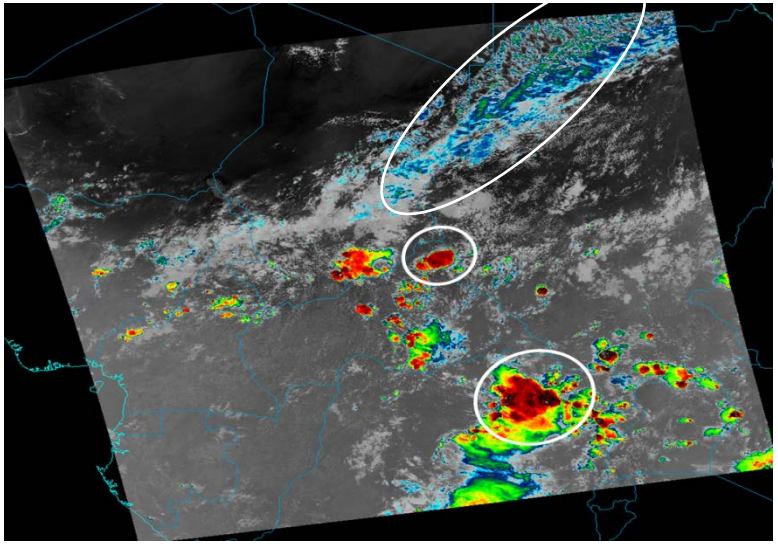
Low Cloud Fraction

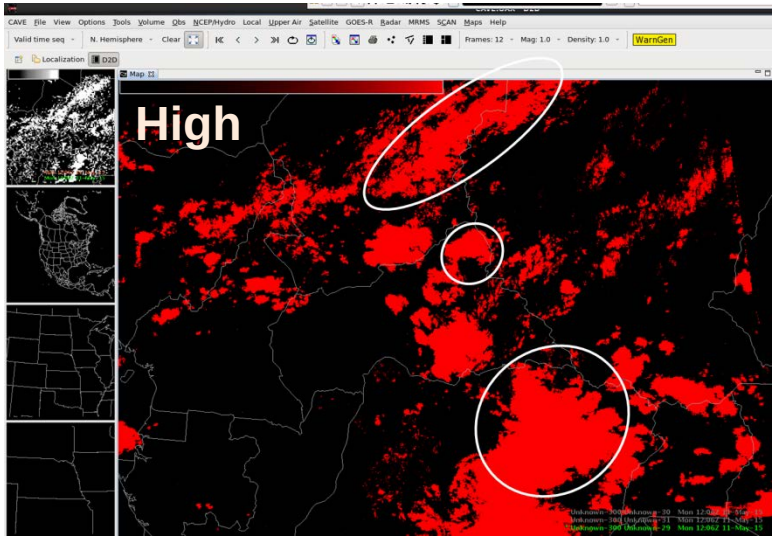


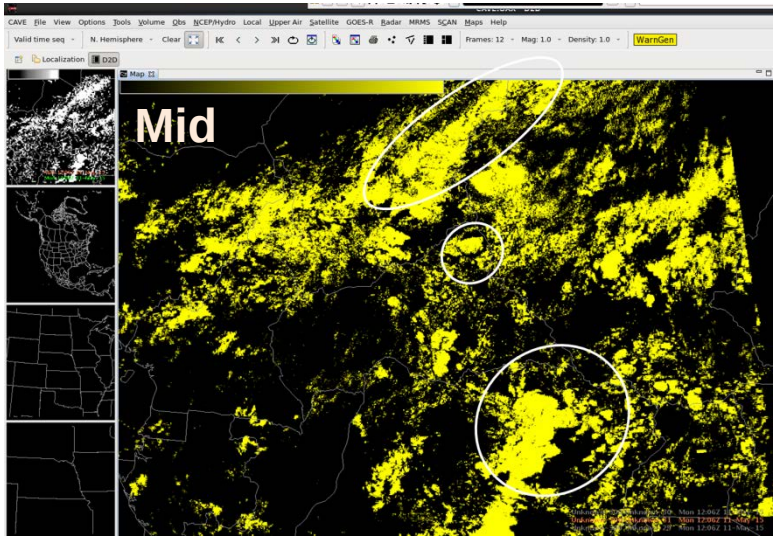
New

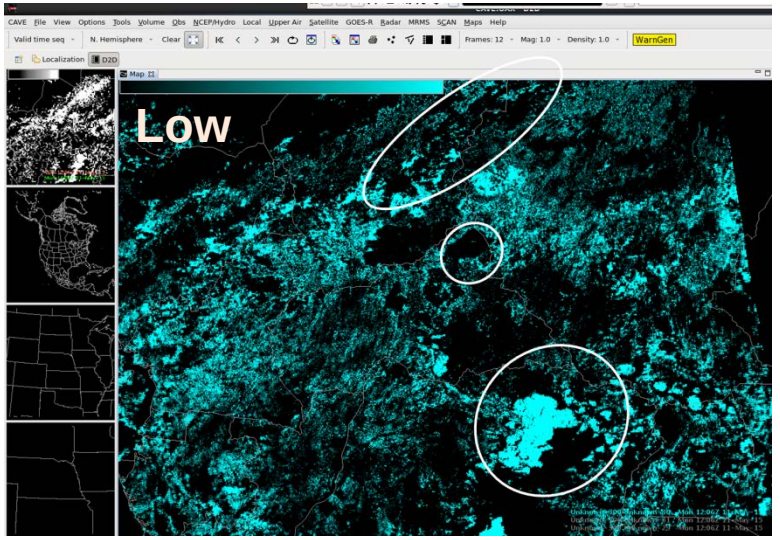
Sample CCL Display in AWIPS-2

VIIRS I-band 5 (left) and cloud fractions from 11 May 2016 at 1202 UTC over central Africa









Summary & Path Forward

- The Enterprise CBH algorithm (for the uppermost layer) is now operational. The CIRA and CIMSS teams will continue to support the STAR AIT for its correct operation and long-term monitoring within the operational frame.
- Our efforts for validation and are ongoing.
  - Add CALIPSO data for validation and use ground-based measurements (ARM data) for nighttime CBH performance test.
- Improvement of CCL products is in progress.
  - The preliminary results show the additional cloud base information can significantly increase lower cloud fractions which have been overlooked by the original algorithm.
- Major algorithm refinements and tests will be completed before J-1 launch, and validation efforts for optimized performance will continue before/after launch.