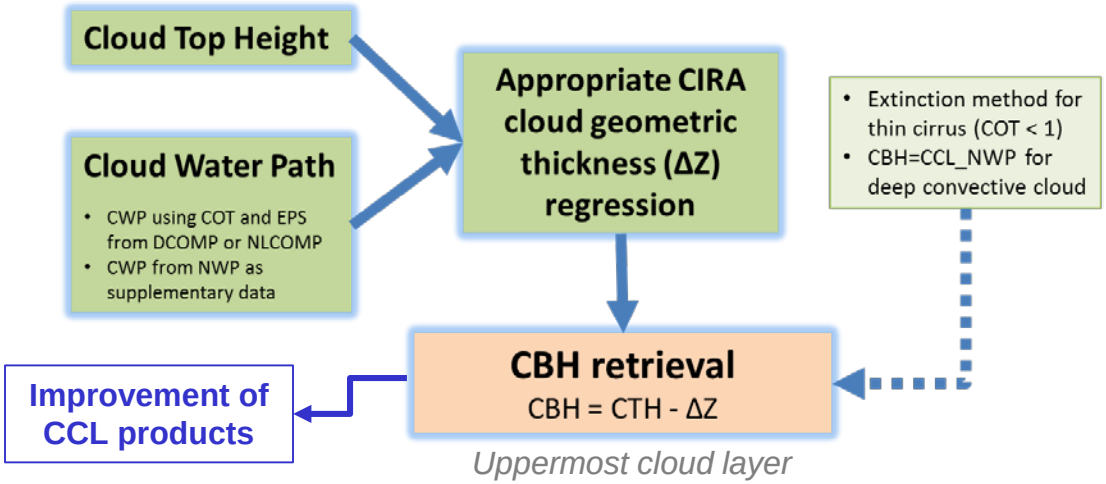
THE NEWLY OPERATIONAL VIIRS CLOUD COVER/LAYERS AND BASE

Yoo-Jeong Noh
(CIRA/Colorado State University)

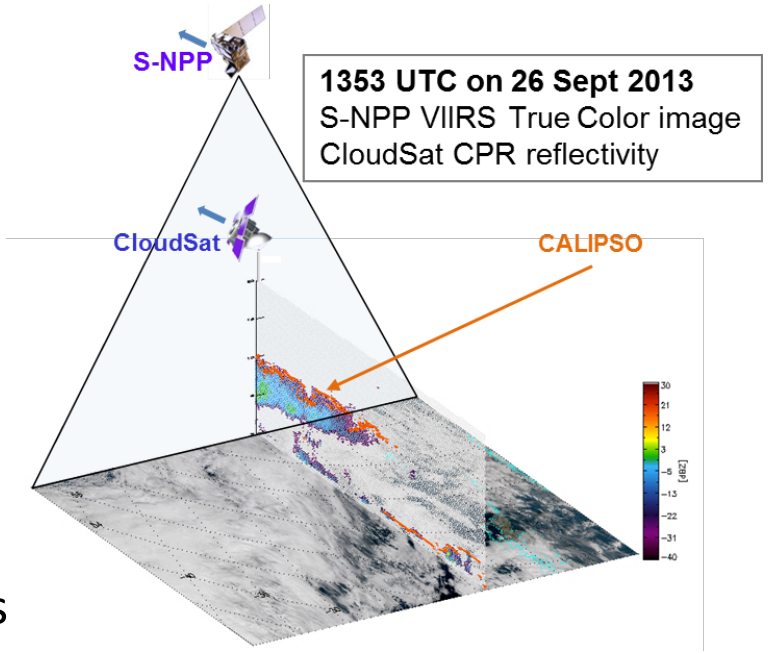
with
Steve Miller, John Forsythe, Curtis Seaman, John Haynes (CIRA)
Andy Heidinger, Dan Lindsey (NOAA/STAR)
Yue Li, Steve Wanzong (CIMSS)

Enterprise Cloud Base Height (CBH)



A new statistical CBH algorithm constrained by Cloud Top Height (CTH) & Cloud Water Path (CWP) using A-Train satellite data (described in *Noh et al. 2017*)

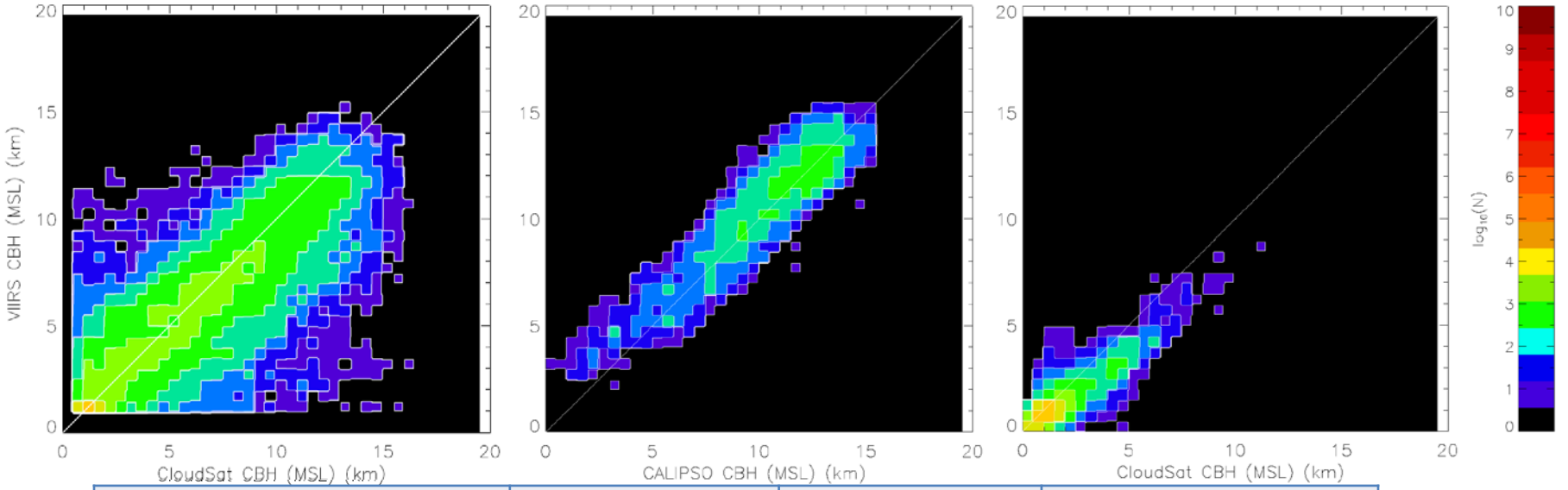
- Knowledge of Cloud Base Height (CBH) is significant to aviation applications and numerical models
- Applied to S-NPP VIIRS and intensively evaluated against CloudSat/CALIPSO (*Seaman et al. 2017*). The new algorithm outperforms the original IDPS CBH algorithm.
- The cloud base information is used for improvement of Cloud Cover/Layers products



CBH validation with CloudSat/CALIPSO Data

(daytime)

All clouds | **Thin clouds** (COT < 1) | **Water clouds**



Errors "within spec" (82599 points for **Sept-Oct 2013**)	All clouds with CloudSat	Thin clouds with CALIPSO	Water clouds with CloudSat/CALIPSO
r^2	0.76	0.84	0.83
Average error (bias)	0.3 km	-0.3 km	0.1 km
Standard deviation error	1.8 km	1.0 km	0.4 km
RMSE	1.8 km	1.1 km	0.4 km

5 times more samples than CloudSat-only validation

The Enterprise CBH yields significantly improved performance over the original IDPS algorithm!
(for all clouds, bias 2.7 km→ 1.8 km and r^2= 0.45→ 0.76, compared to IDPS)

"**Within Spec**" evaluation (CTH within 1 km of CloudSat CTH if COT > 1, or within 2 km if COT < 1)

Product Overview and Status

- Performance Summary

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

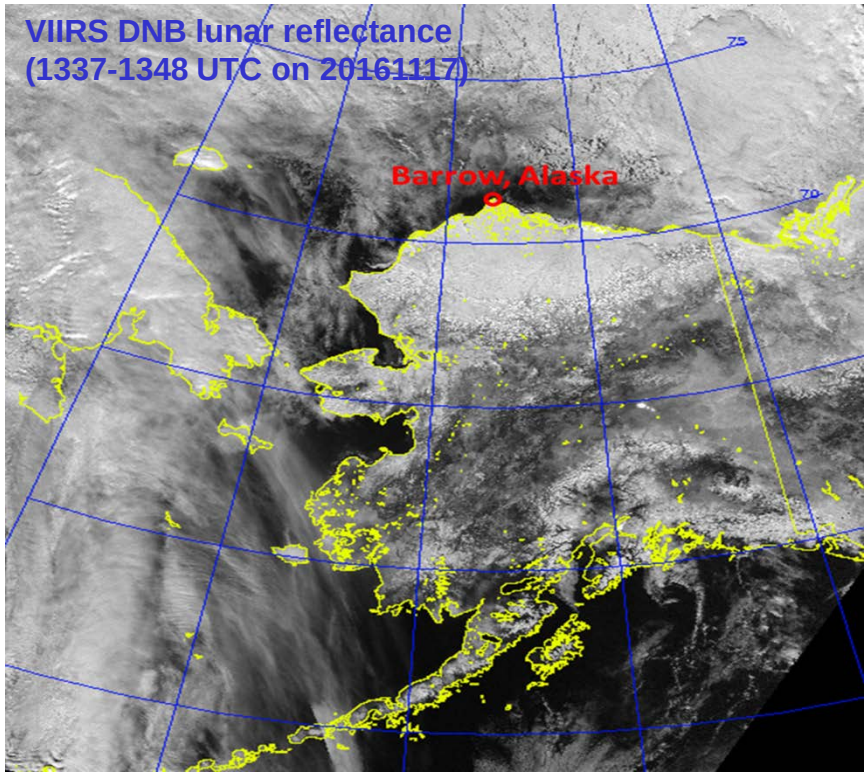
(from 5-month matchup comparisons in 2015 between VIIRS CBH and CloudSat observations)

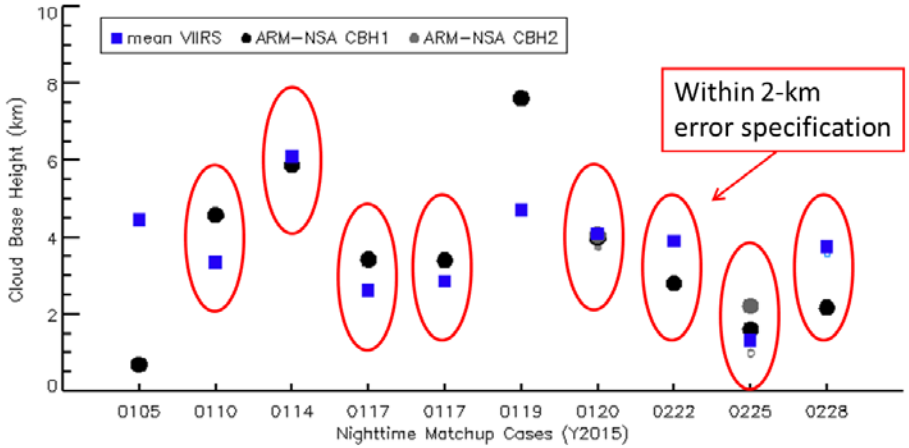
- The Enterprise CBH algorithm code with the ATBD has been delivered to the STAR Algorithm Implementation Team, now running in the operational frame.
- Publications in 2017
  - Seaman et al. 2017: Cloud Base Height Estimation from VIIRS. Part I: Operational algorithm validation against CloudSat. *J. Atmos. Ocean. Tech.*, 34(3), 567-583.
  - Noh et al. 2017: 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.*, 34(3), 585-598.

Work in progress (CBH and CCL)

- Assess the nighttime performance using ground-based measurements
- Improve CCL products using the cloud base information
- Apply the algorithm to multi-satellite platforms
- Continue to validate the products with CloudSat and CALIPSO
- Display test of the products for users

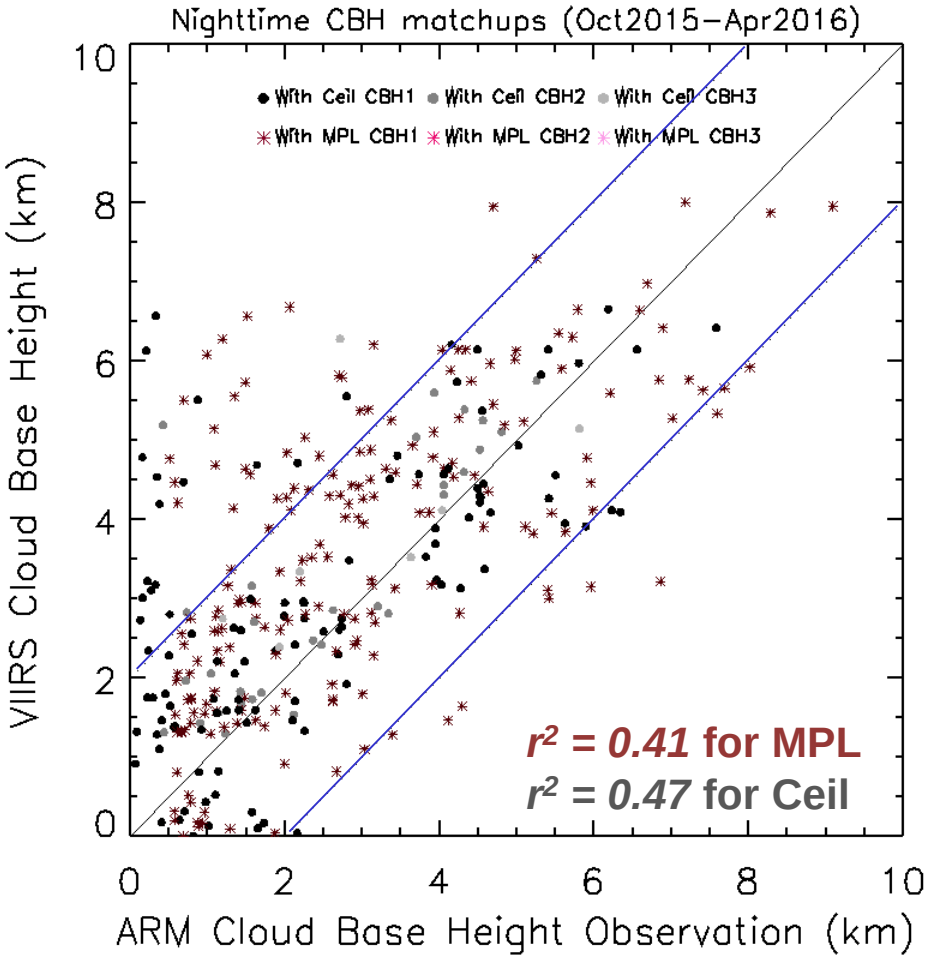
Nighttime CBH algorithm performance





- Nighttime CBH performance using ARM measurements (SGP/NSA sites)
- CBHs retrieved in CLAVR-x. Cloud optical properties from a nighttime cloud algorithm (NCOMP) based on a lunar reflectance model for VIIRS DNB (supplementary NWP data if no valid values)
- Validation for an extended period over Alaska
  - 581 matchups from October 2015 to April 2016 (NSA in Barrow, AK)
  - Ceilometer, Micro-pulse Lidar (MPL)
- Check local weather conditions with surface temperature/precipitation data
- Co-located CALIPSO data for selected multi-layered cloud cases

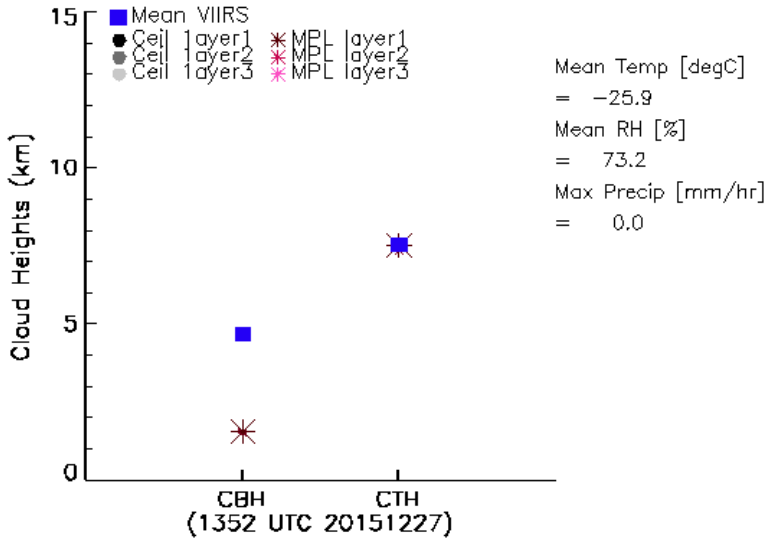
Nighttime CBH algorithm performance

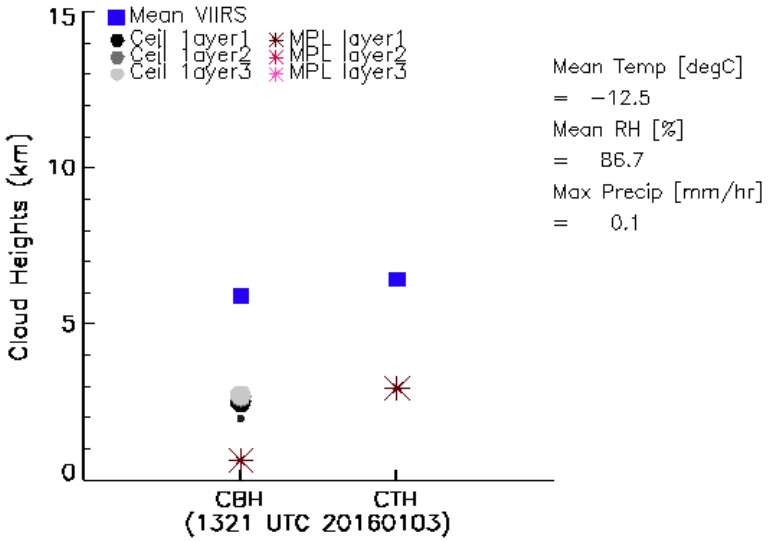


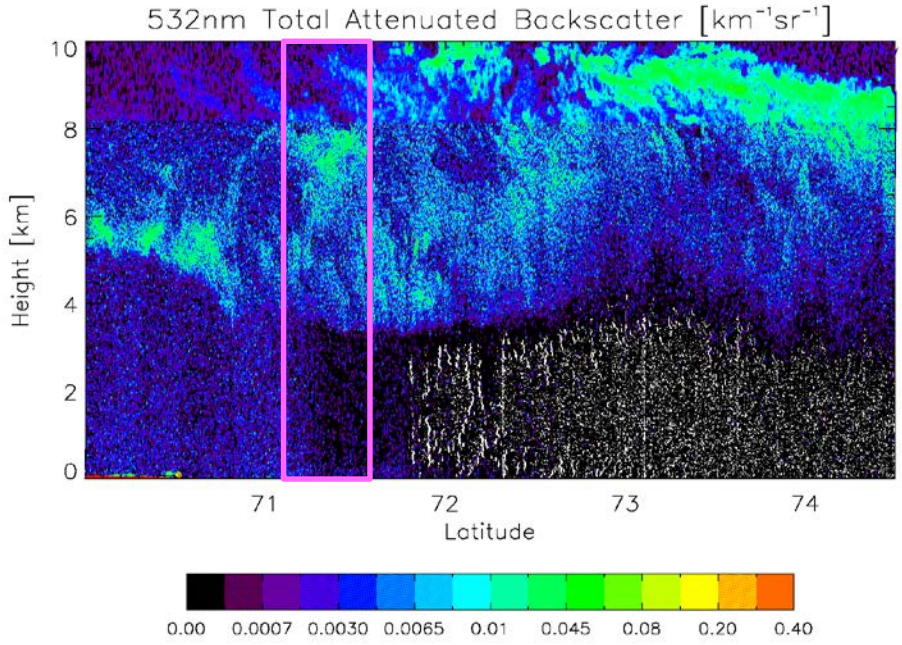
Symbols - CBH1: lowest, CBH3: highest from surface measurements (*precip cases excluded*)

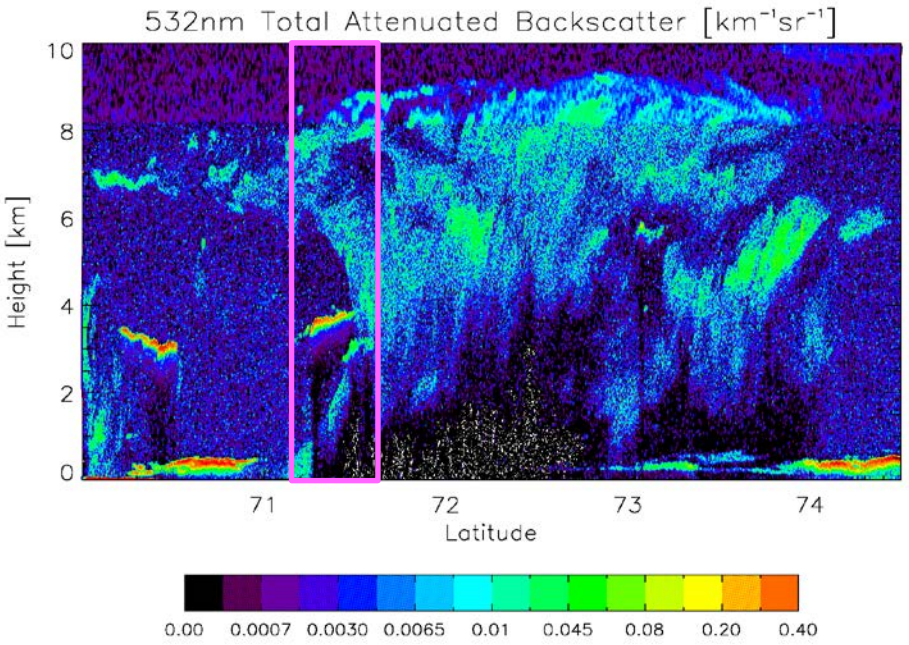
- Comparisons between Ceilometer/Micro-pulse Lidar (MPL) and VIIRS CBHs
- Low clouds (or ice fog) often observed from the ceilometer (below 500 m). When multiple CBHs are available from ground observations, one closer to VIIRS CBH was selected
- **CTH is critical to the CBH accuracy. CBHs from Ceilometer and MPL only when CTHs from MPL and VIIRS are within 2-km error range**
  - ✓ 62 % CBHs from Ceilometer and 76.6 % from MPL within VIIRS 2-km CBH error range

Case study utilizing CALIPSO for multi-layers

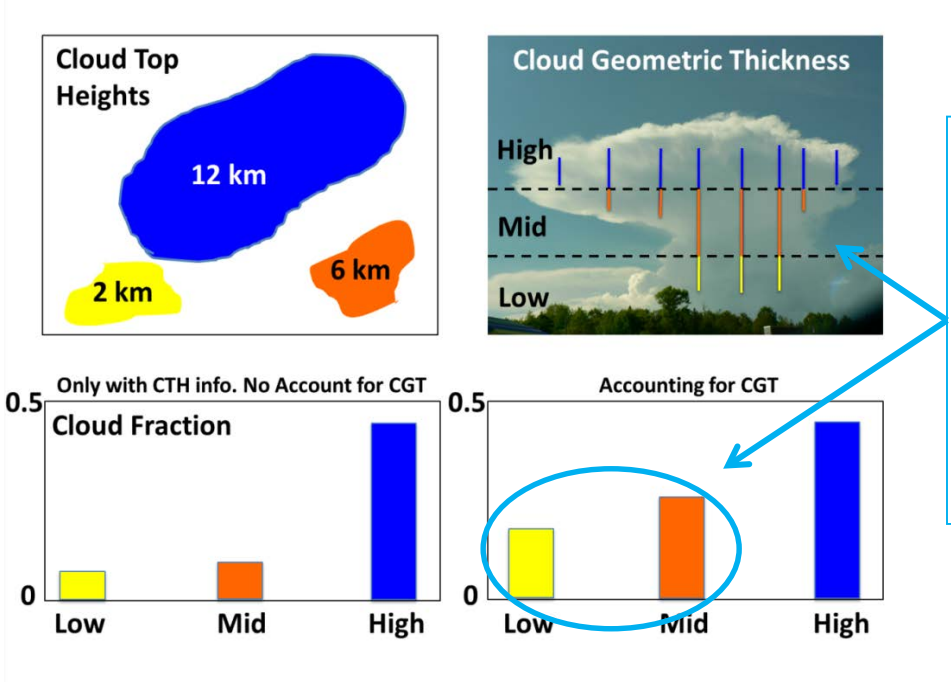








Improvement of Cloud Cover/Layers

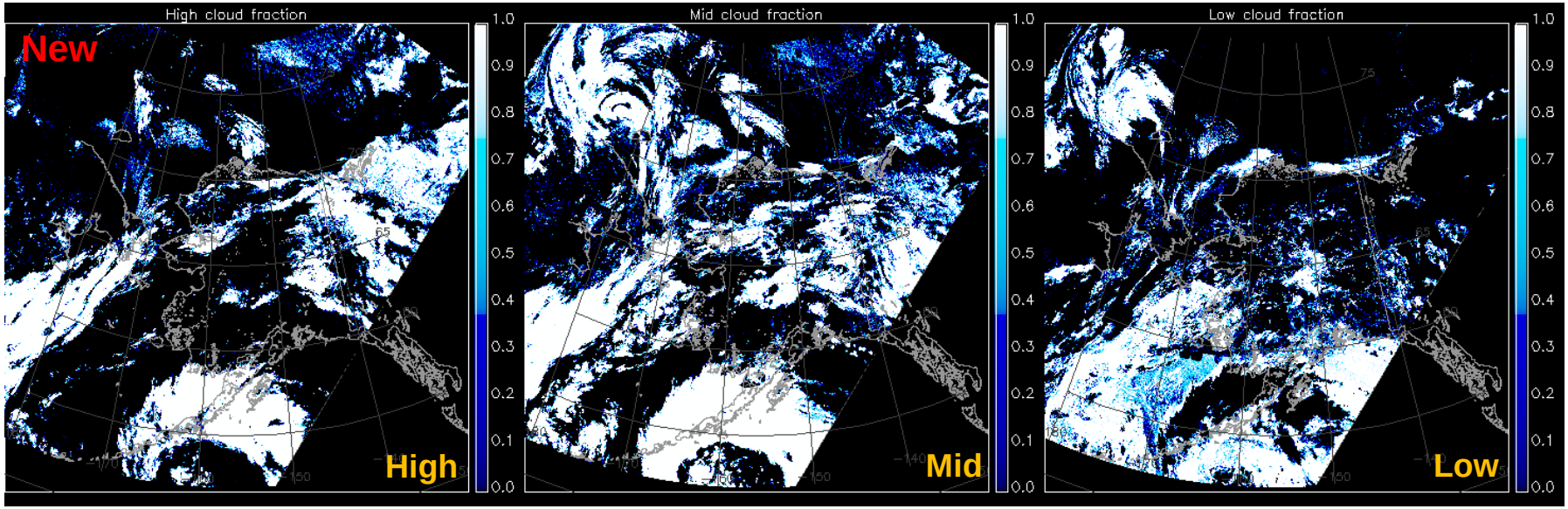


The CBH information can be used to modulate the layered cloud fraction (high/mid/low) by introducing additional cloud coverage at lower (unobserved via satellite) levels of the profile

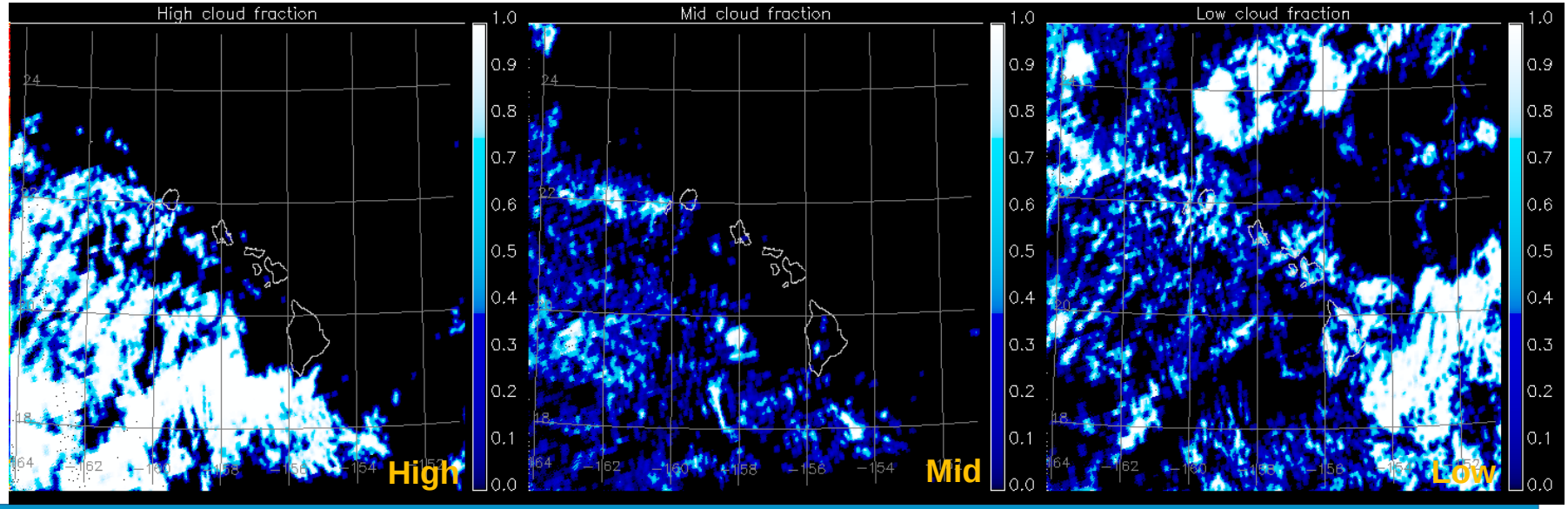
- Implemented the updated algorithm in the CLAVR-x system
  - The current high and low layer thresholds: **350 hPa** and **642 hPa**
  - To be expanded in layers defined by 5 flight levels (NOAT's request)
- Applied to VIIRS (Alaska and Hawaii)
- Applicable to geostationary satellites: Himawari-8 AHI, GOES-16 ABI

Cloud Cover/Layers over Alaska and Hawaii

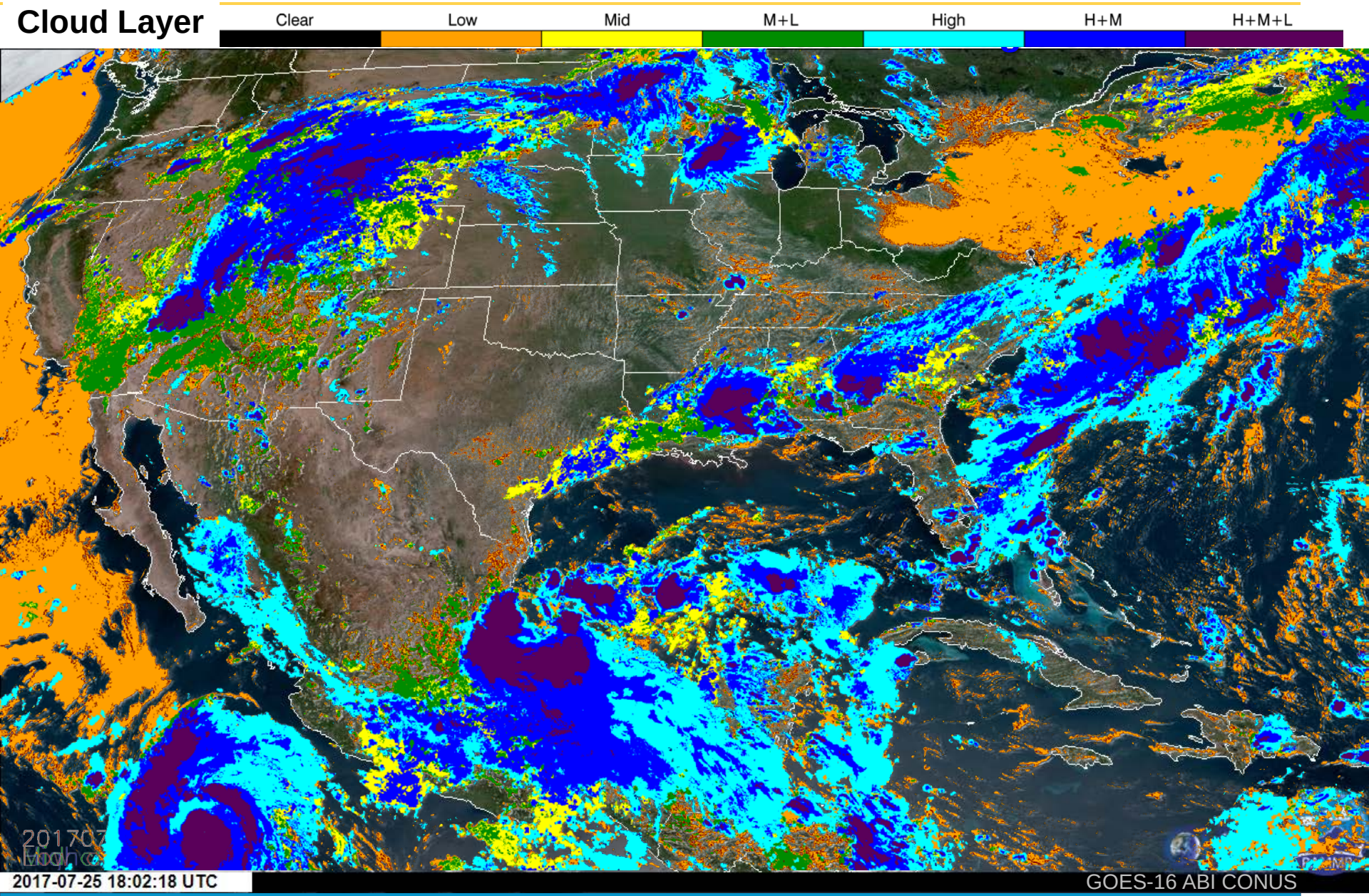
(S-NPP VIIRS 1355 UTC 2016-02-29 **Alaska**) **Increases of Middle and Low Cloud Fractions by using the CBH information**



(S-NPP VIIRS 2311 UTC 2017-08-06 **Hawaii**)

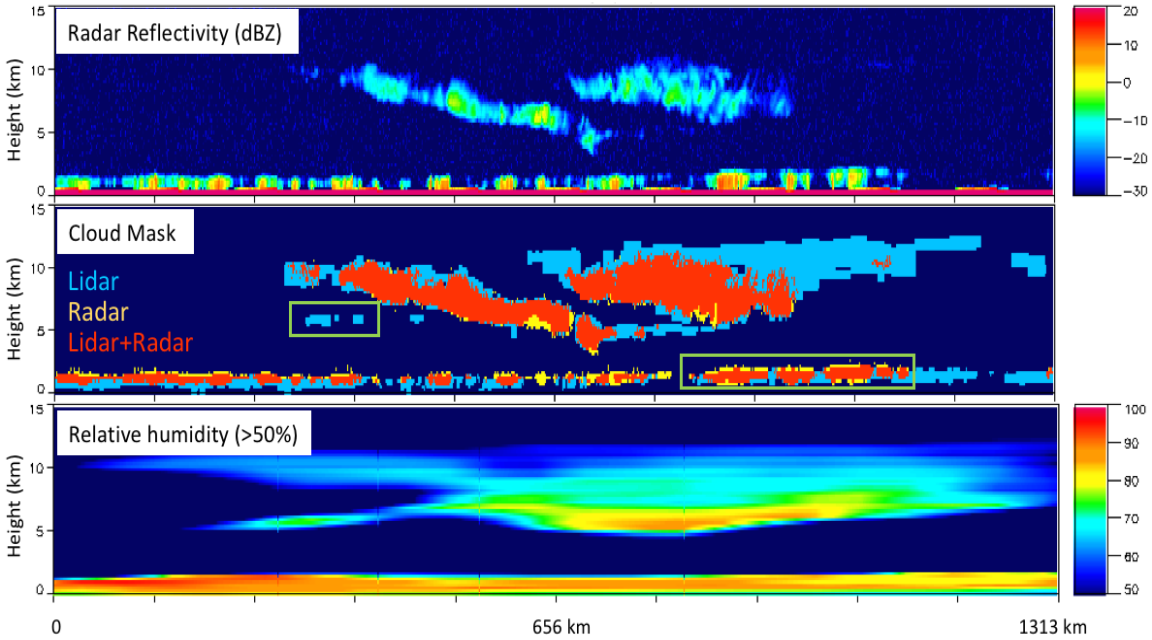


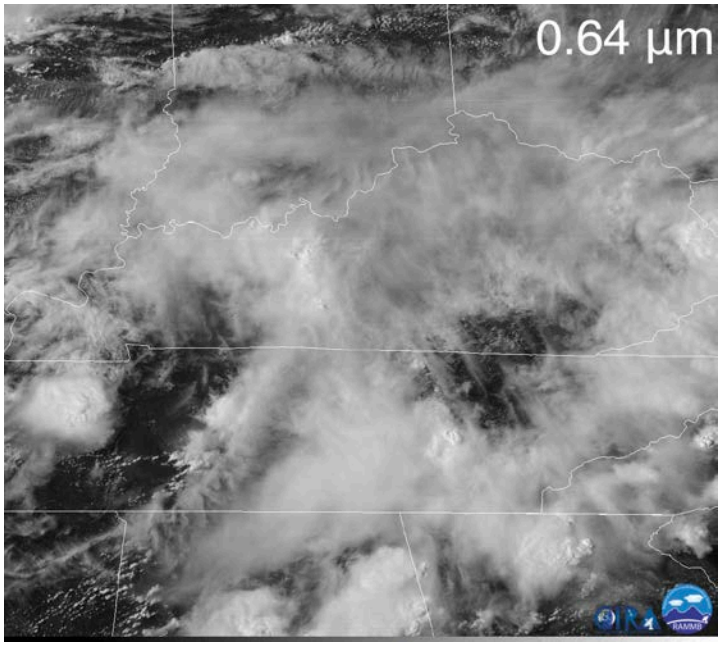
Improvement of Cloud Cover/Layers



Leveraging efforts for multi-layer clouds

- Interface with research from our GOES-R Risk Reduction project to improve the characterization of multilayer clouds
- Use statistics from CloudSat and NWP layer moisture in ambiguous situations including multilayers



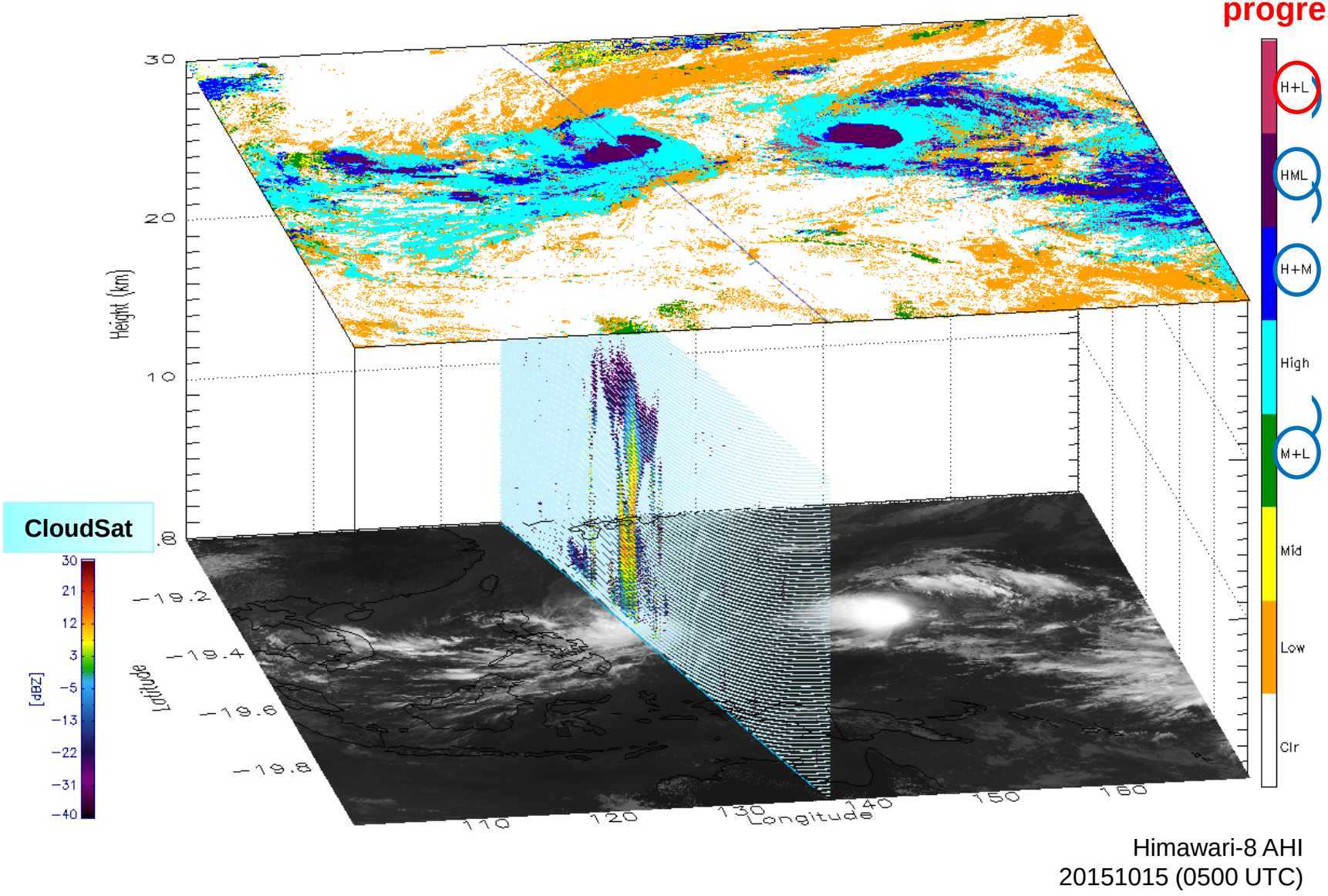


- Use a multi-spectral approach to aid in determination of separation distance between cloud layers
  - 1.38 µm cirrus channel is in a WV absorption band: most reflectance originates from cirrus
  - 0.64 µm red channel is sensitive to upper and lower clouds

Improvement of Cloud Cover/Layers

Validation of Cloud Cover/Layers with CloudSat

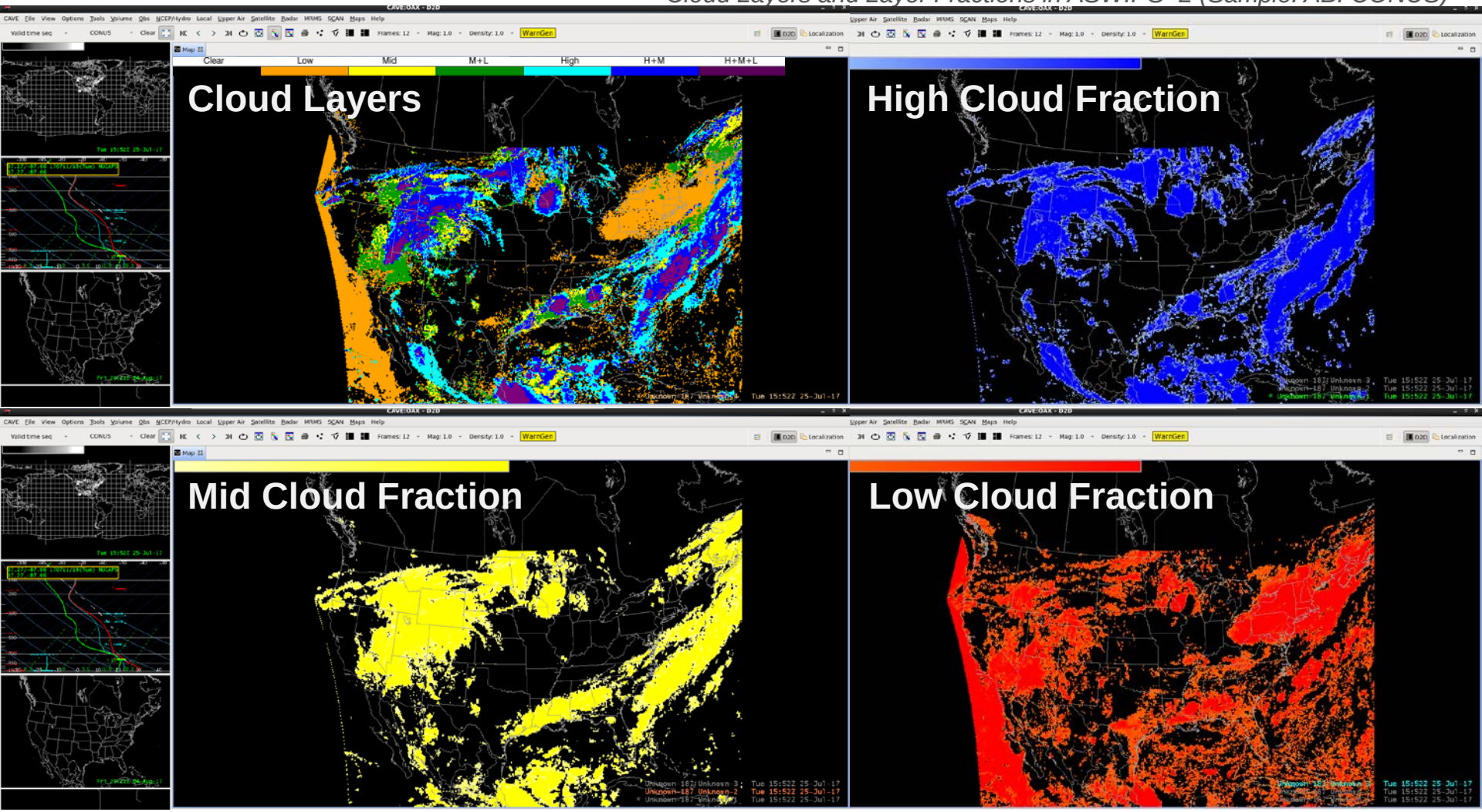
Work in progress



Himawari-8 AHI
20151015 (0500 UTC)

Sample CCL Display in AWIPS-2

Cloud Layers and Layer Fractions in ASWIPS -2 (Sample: ABI CONUS)



- **Also display in SLIDER developed at CIRA for real-time GOES-16 imagery** (rammb-slider.cira.colostate.edu, developed at CIRA, sample: http://col.st/YawIS)

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 algorithm team for its correct operation and long-term monitoring within the operational frame.
- Ongoing efforts
  - Continue to validate the products with CloudSat and CALIPSO
  - Assess the nighttime performance using ARM ground measurements
  - Apply the algorithm to multi-satellite platforms
  - Test the product display for users (AWIPS-2 and SLIDER)
- Improvement of CCL products employing the new cloud base
  - Significantly increase lower cloud fractions with vertically extended cloud layer information, further improvement for multilayer clouds
- Major algorithm refinements have been completed. Validation efforts for optimized performance will continue before/after launch of JPSS1.