Enterprise Cloud Base

VIIRS Cloud Base Height Algorithm Improvement and Evaluation Using CloudSat

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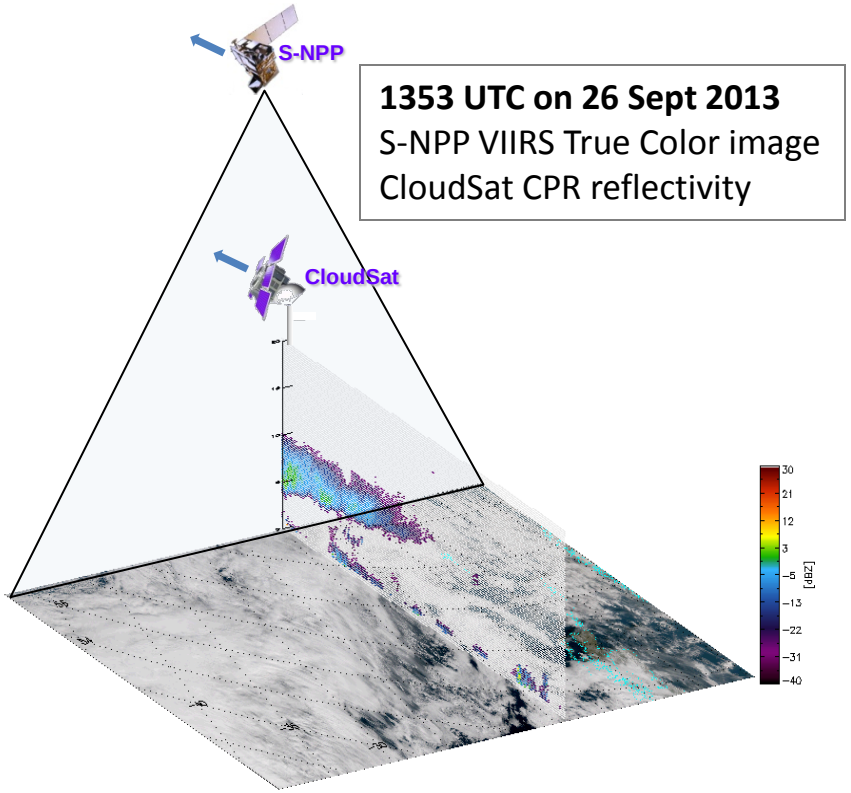
Introduction

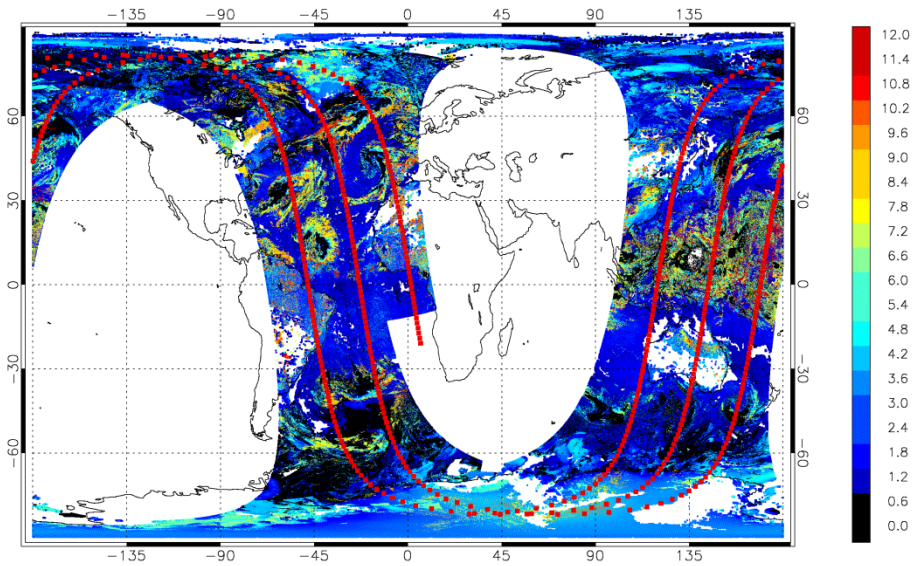
- **CBH (Cloud Base Height) is important for aviation.**
  - ✓ Cloud ceiling and visibility - critical to the general aviation community
- **CBH is also important for closure of the Earth's radiation budget in climate modeling.**
- **CBH helps improve Cloud Cover Layer products.**
- **A few attempts:**
  - ✓ Hutchison (2002) developed algorithm to determine cloud base height (CBH) from VIS/IR observations from MODIS.
  - ✓ Chakrapani *et al*. (2002) and Minnis *et al*. (2005) developed CBH empirical parameterizations from GOES and ARM data.
- **We have been working on VIIRS CBH CAL/VAL and improvement using CloudSat data.**

Matching VIIRS with CloudSat



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

VIIRS CBH [km] with CloudSat overpass track (red)
from 1334-1812 UTC on 26 Sept 2013



- Suomi-NPP and CloudSat are in the same orbital plane, but at different altitudes
- CloudSat and 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
- Parallax-corrected

VIIRS IDPS CBH Algorithm

VIIRS IDPS CBH algorithm for liquid clouds:

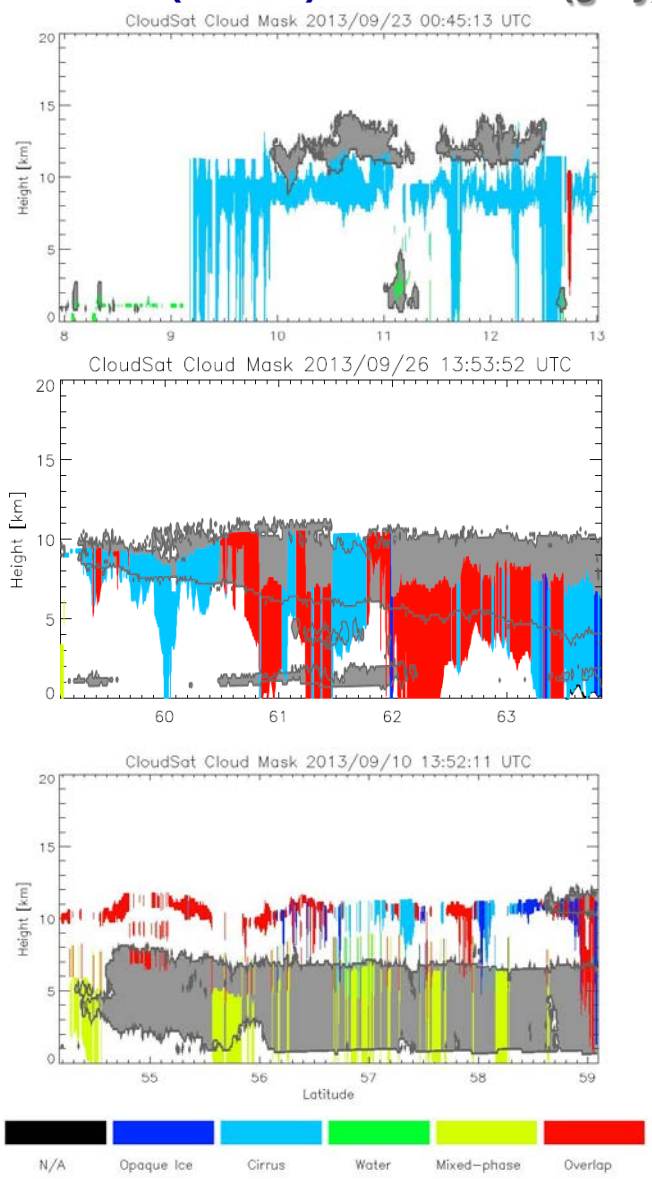
$$CBH = CTH - \left(\frac{LWP}{LWC}\right), \quad LWP = \frac{2\tau\rho r_e}{3}$$

- ✓ Red variables come from upstream retrievals.
- ✓ LWC is pre-defined average value based on the upstream cloud type retrieval.
- ✓ CBH for ice clouds is similar (T-dependent IWC).

- CBH requires upstream retrievals of cloud properties which issues directly impact CBH retrieval.
- As part of the JPSS Cloud Cal/Val efforts, our evaluation showed **the IDPS CBH algorithm provided only marginal skill.**

Sample comparison results are shown at right. CloudSat Cloud Mask (gray, from 2B-GEOPROF) with VIIRS overlaid (IDPS CTH/CBH colored by cloud type)

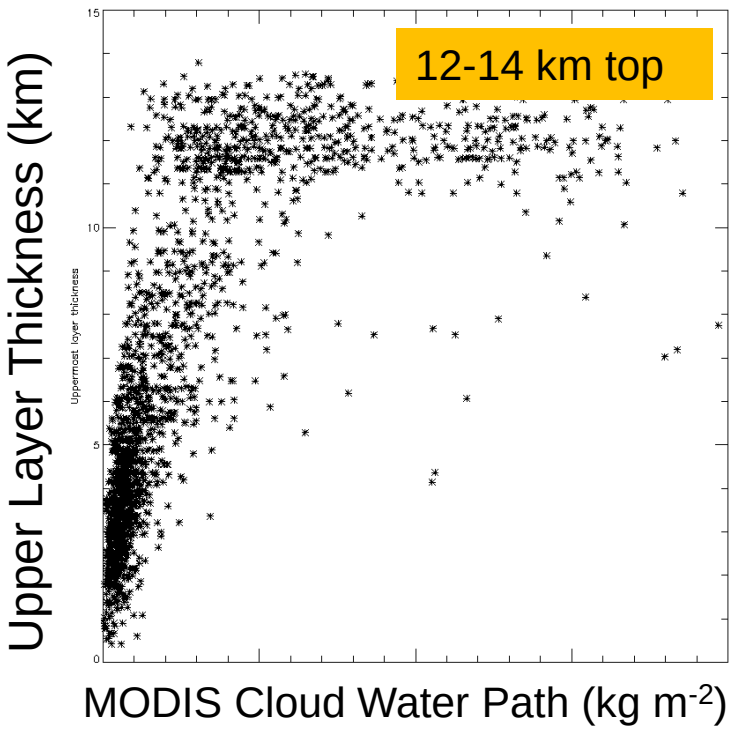
VIIRS IDPS (colored) vs. **CloudSat (gray)**



Enterprise CBH Algorithm

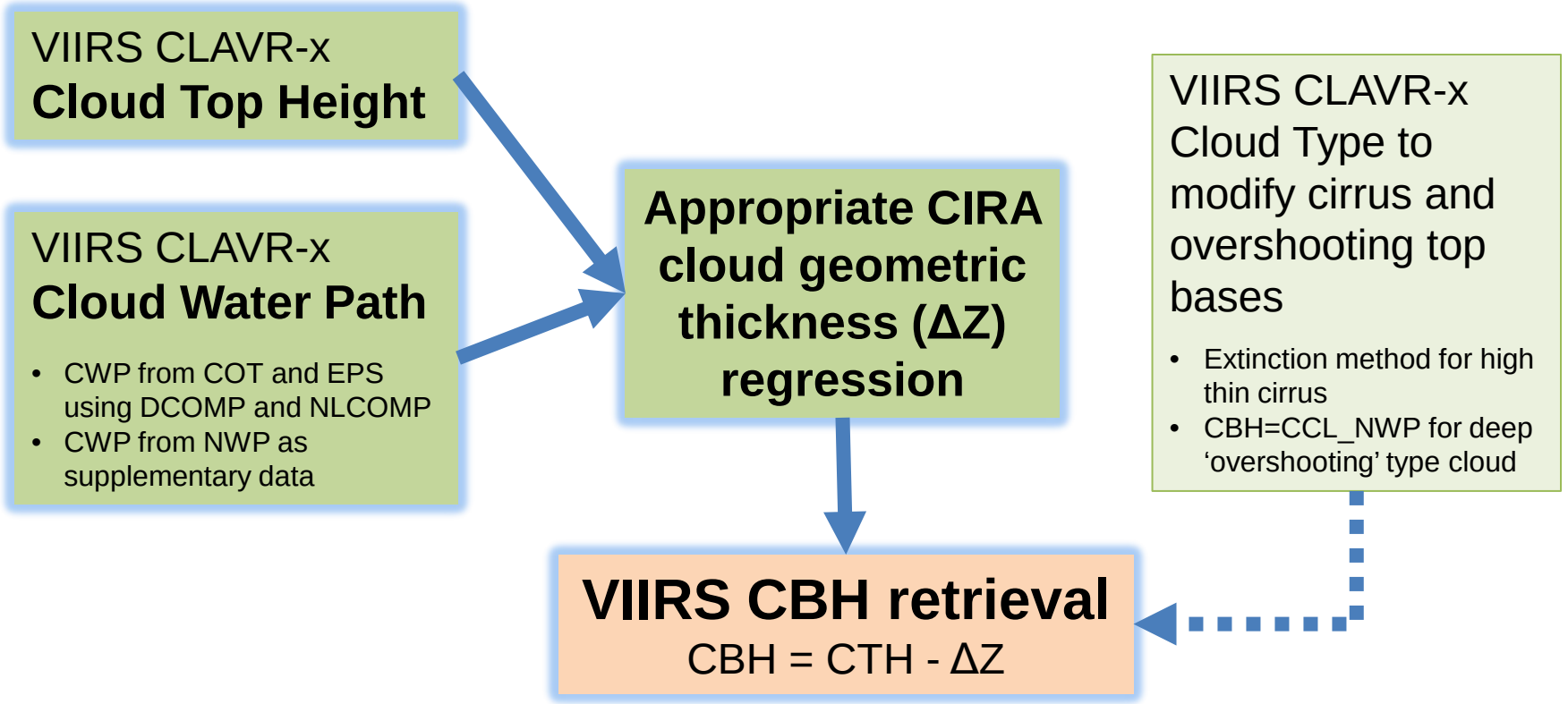
CIRA's new statistical Cloud Base Height Algorithm using A-Train satellite data

- Linear regression fits were performed between water path and geometric thickness for cloud top heights residing in 2 km vertical bins up to 20 km.
- The median CWP value in each 2 km CTH bin was determined, and a linear regression above and below this value was performed.
- An initial two-piece linear regression was performed for July daytime data from 2007-2010 (1743 CloudSat/CALIPSO granules).



Cloud geometric thickness of the uppermost layer from the combined **CloudSat/CALIPSO** cloud profile product (2B-Geoprof-Lidar) and **MODIS Cloud Water Path** (MOD06)

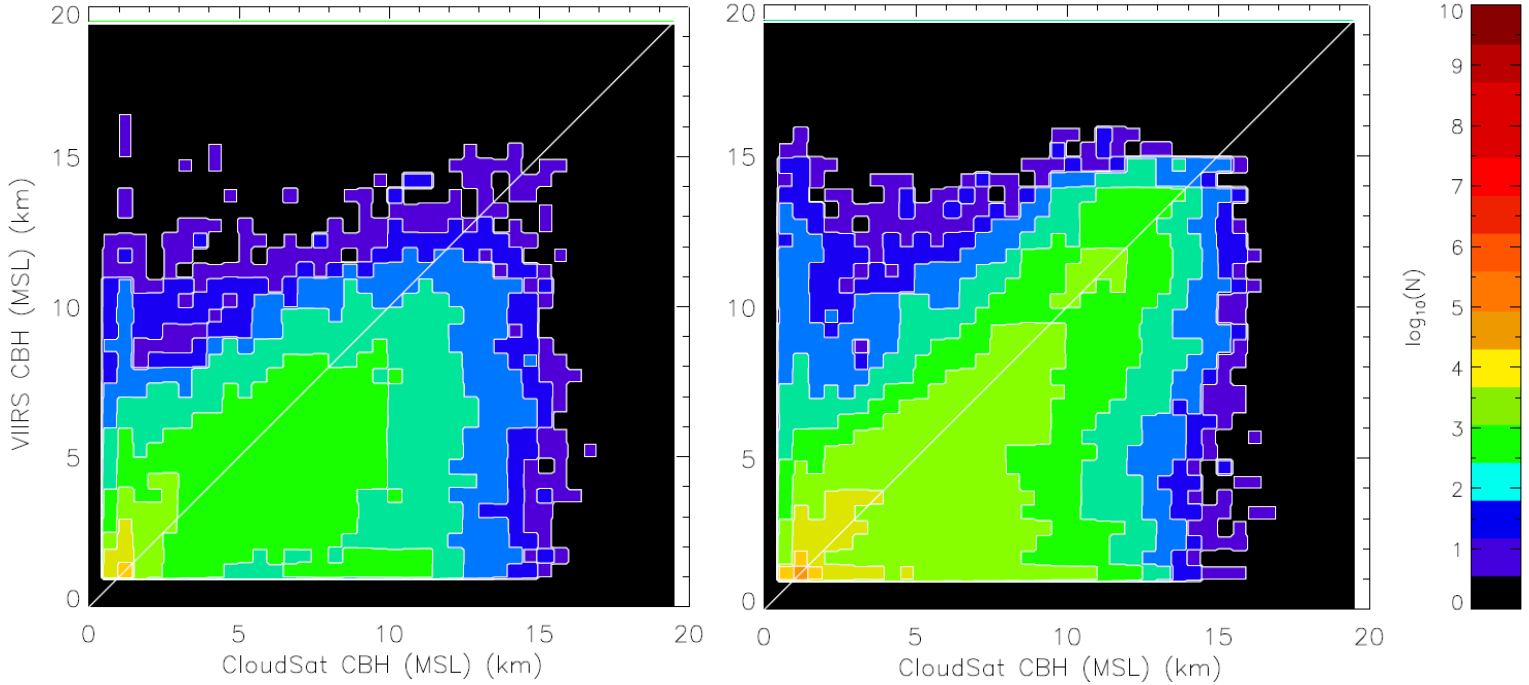
Enterprise (Uppermost Layer) Cloud Base Data Flow



Investigating a Switch of Algorithms

IDPS vs. Enterprise CBH: "All Clouds"

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



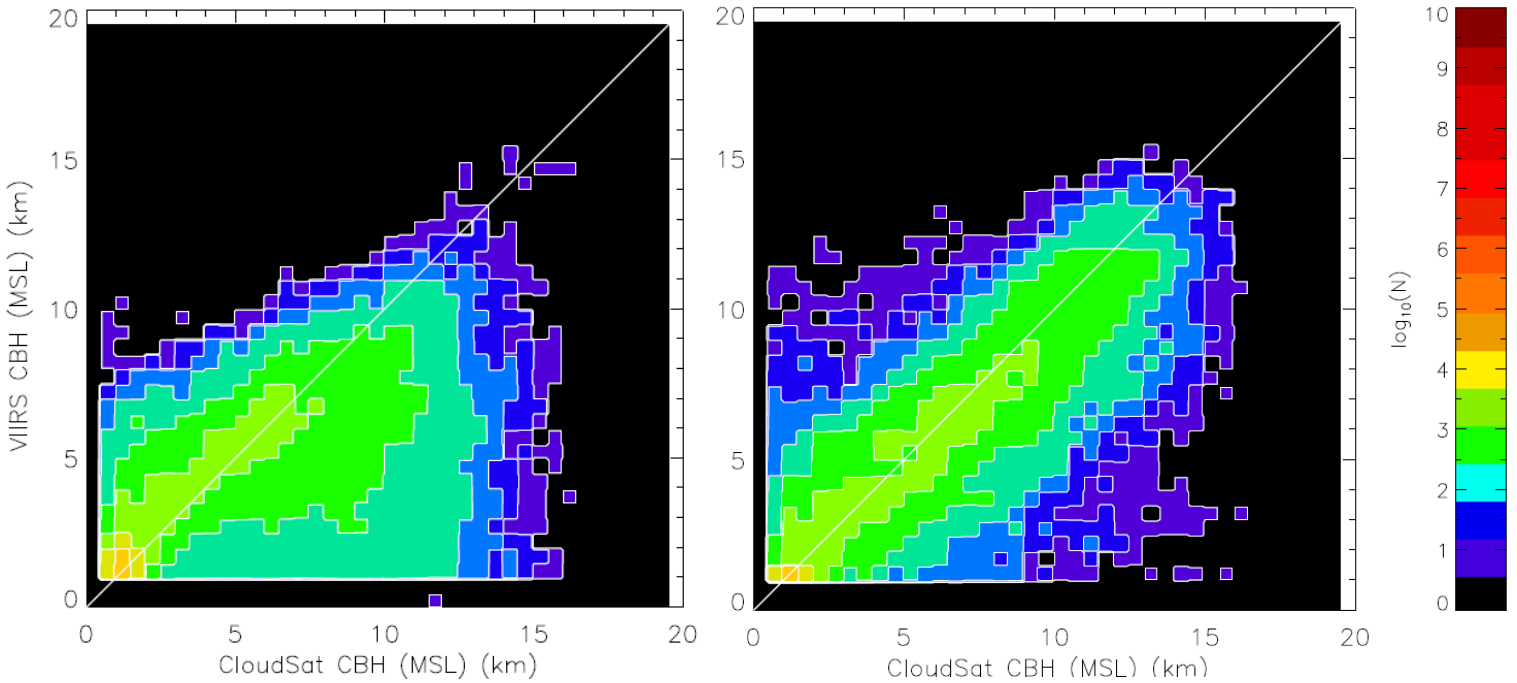
- "**All Clouds**" evaluation: all clouds observed by CloudSat and VIIRS for the general performance
- 1540 VIIRS granules and 202642 matchup points for Sept-Oct 2013 cases

CBH [km]	Avg error (bias)	RMSE	Std of error	r^2	
IDPS	1.0	3.3	3.1	0.286	
Enterprise	1.0	3.0	2.8	0.427	✓ Better

The enterprise CBH performs better!

IDPS vs. Enterprise CBH: "Within Spec"

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)

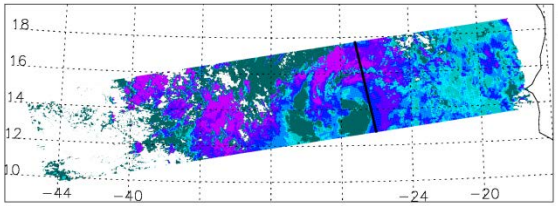
CBH [km]	Avg error (bias)	RMSE	Std of error	r^2
IDPS	0.7	2.7	2.6	0.452
Enterprise	0.3	1.8	1.8	0.760

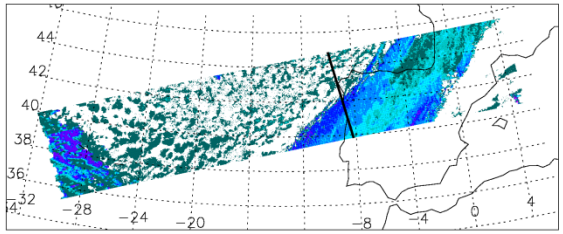
✓ **Much better!**

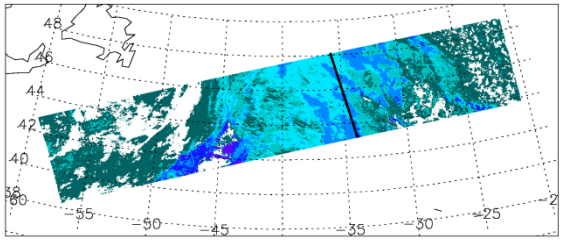
Sample matchup comparisons

The original IDPS with CLAVR-x input => Enterprise CBH

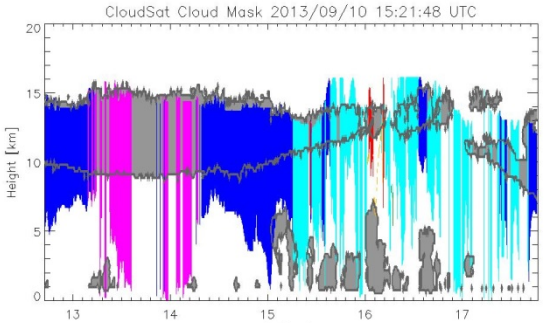
Horizontal CBH contours

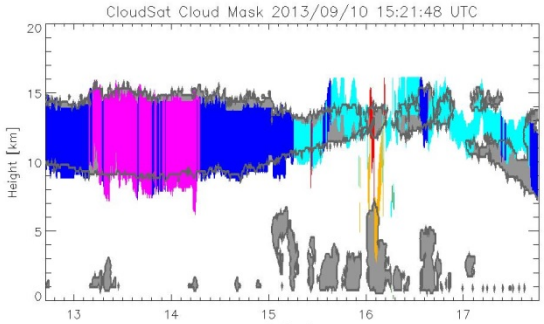


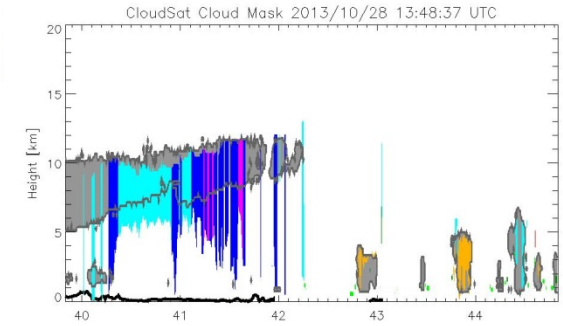


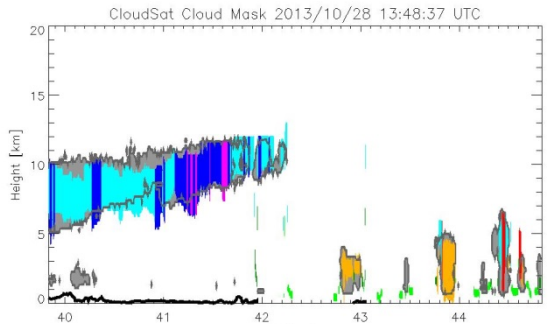


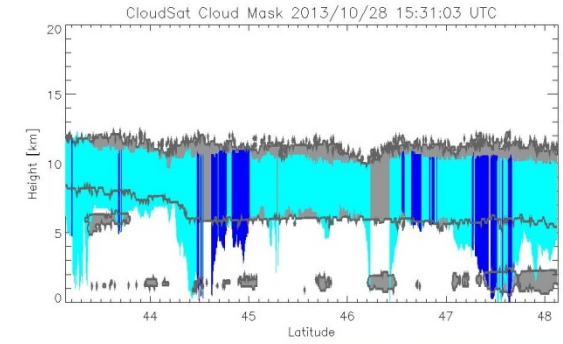
Enterprise CBH [km]

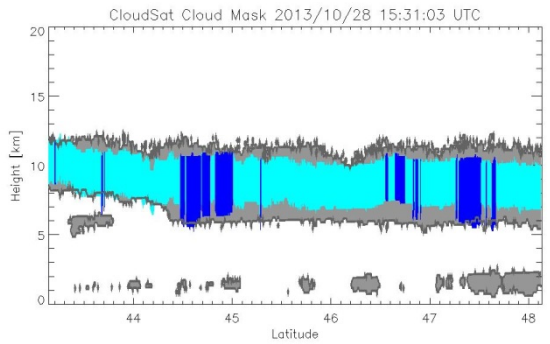


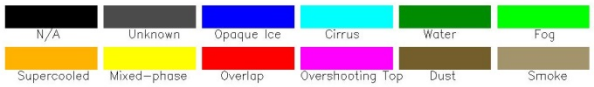










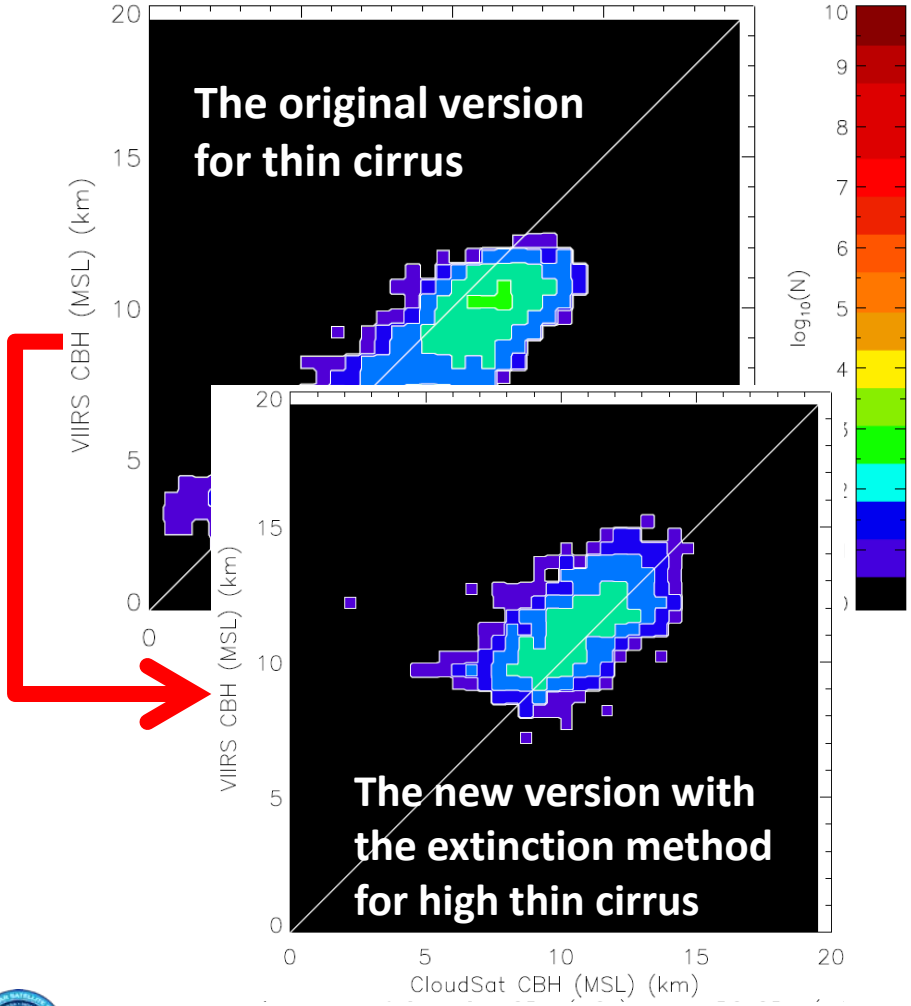


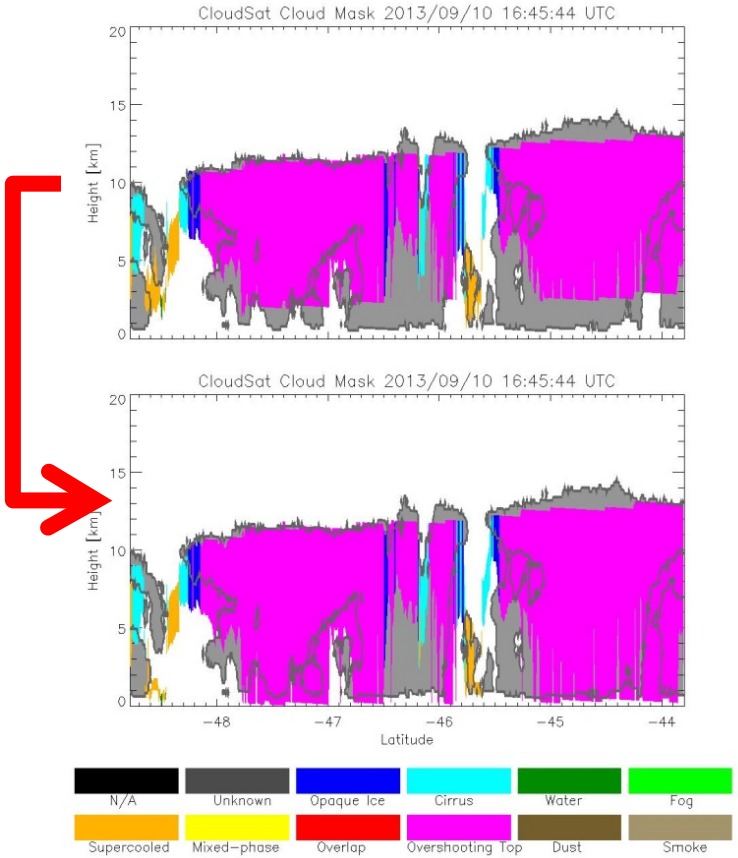
CloudSat Cloud Mask (gray) and VIIRS CTH/CBH (colored by cloud type)

Ongoing work to provide an optimized CBH retrieval

For high thin Cirrus, CALIPSO-based extinction method by Yue Li (CIMSS) and Andy Heidinger (NOAA/STAR)

For deep convective clouds, CBH = Convective Condensation Level from NWP



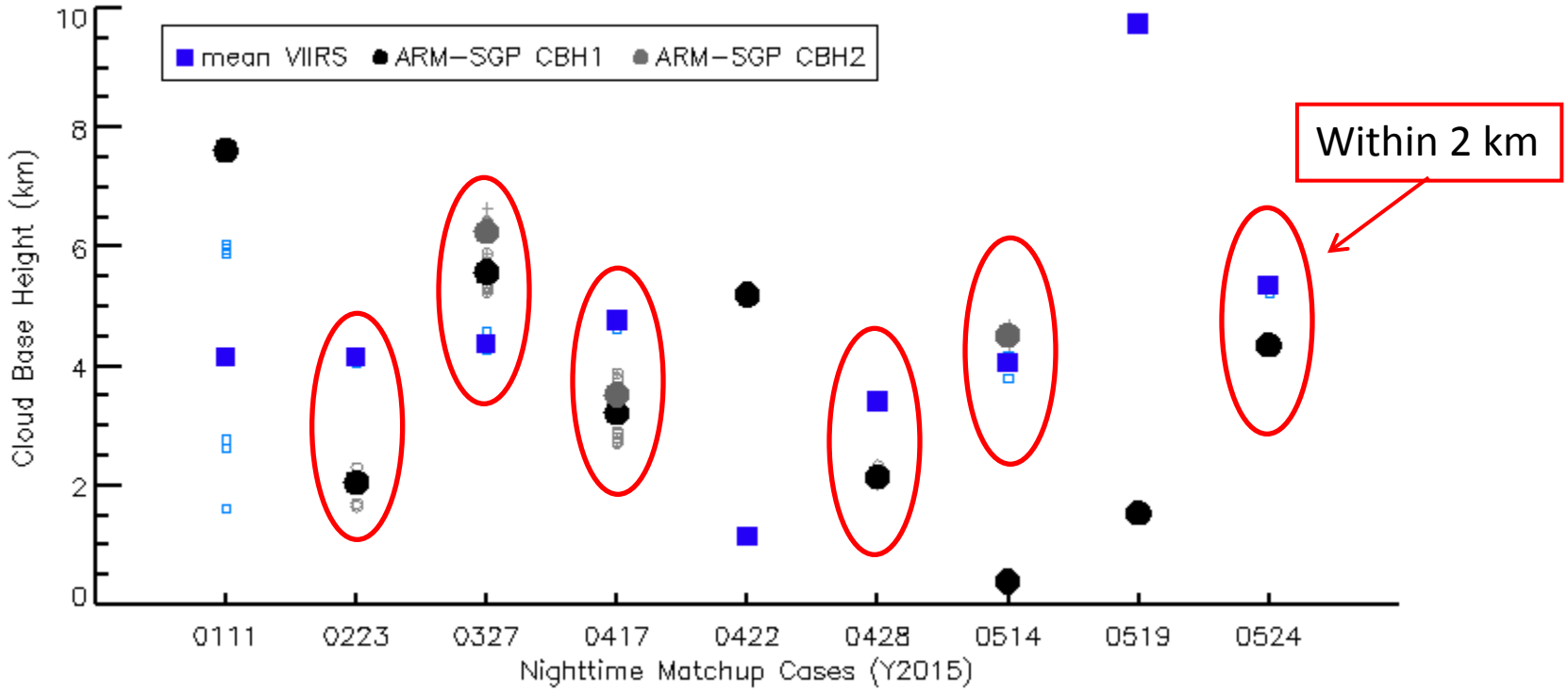


Combined with the statistical method in the current CLAVR-x CBH routine

New work in progress

Nighttime CBH algorithm performance

Preliminary results for the enterprise CBH and ARM SGP-C1 ceilometer data
(9 valid cases within a 1-km and 3-min matchup window in Jan-May 2015)

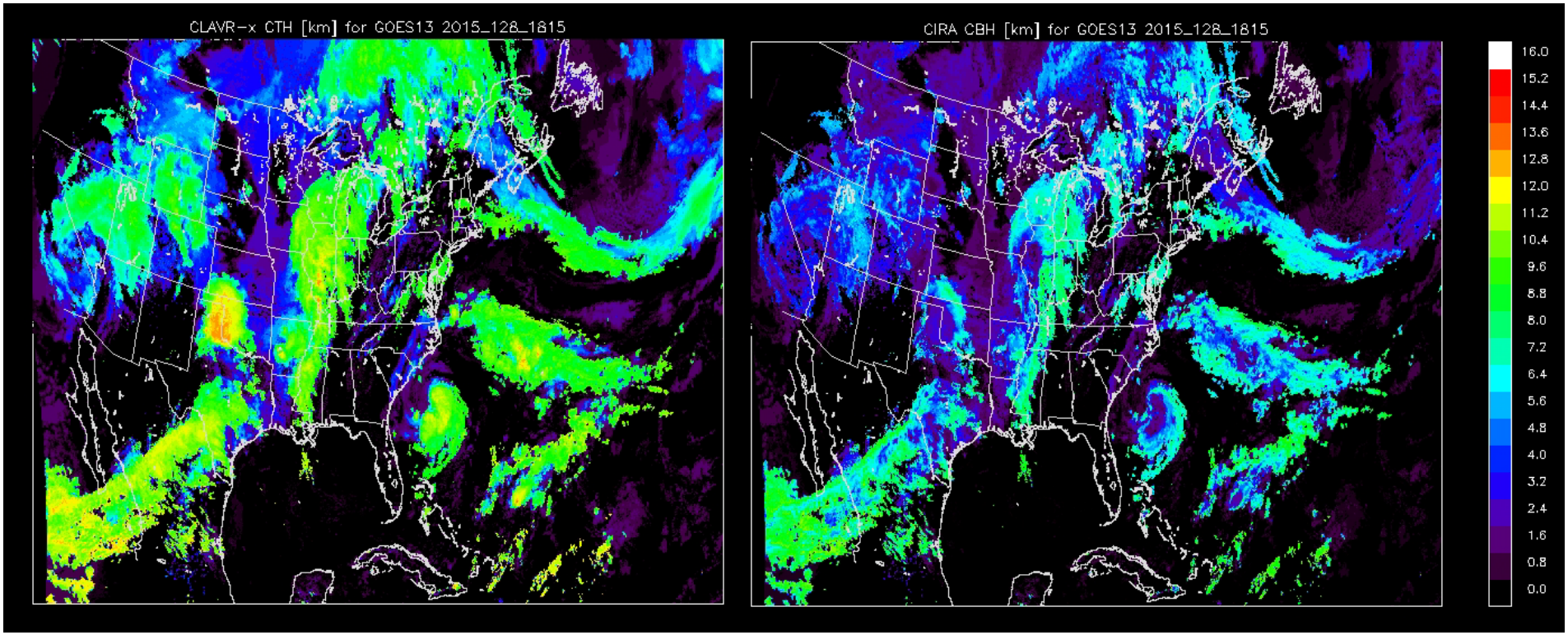


- ✓ *NLCOMP or NWP products used for nighttime CWP*
- ✓ *Ongoing work using ARM NAS (Barrow, Alaska) ceilometer data*

Apply to geostationary satellites (I)

GOES-W and GOES-E

Sample CTH and CBH from GOES-13 on 8 May 2015 (1815 UTC)



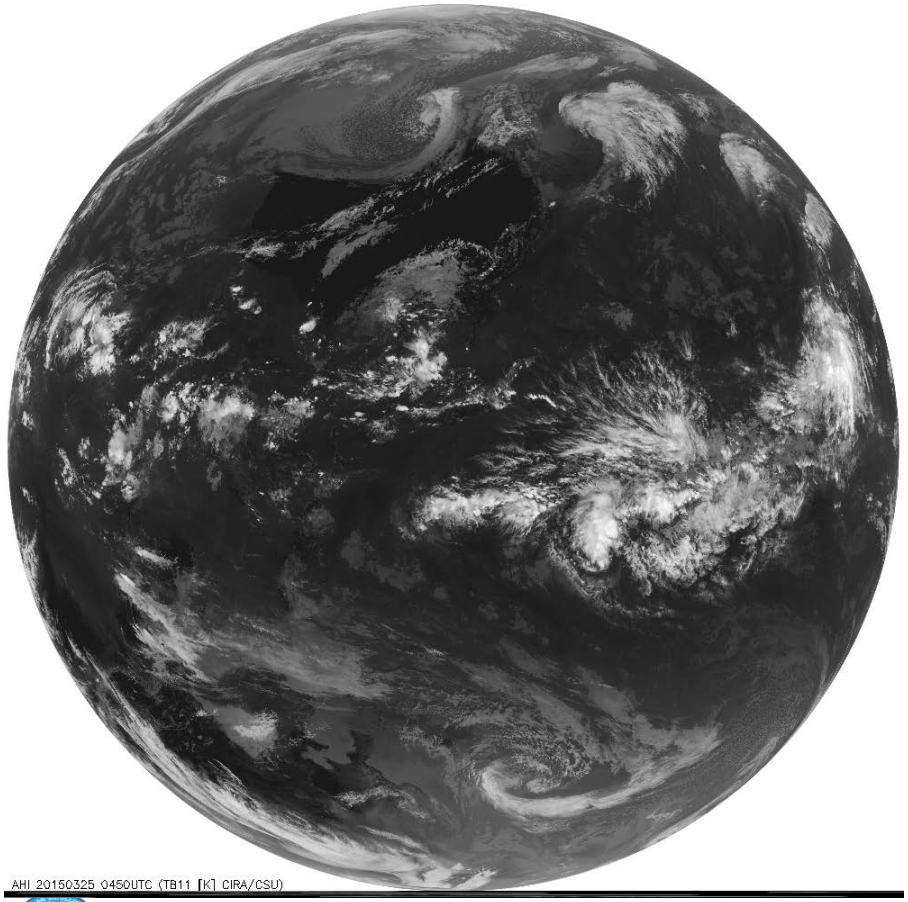
CTH [km] **CBH [km]**

Similar CBH data (lower layer CBH) being produced from the NASA Langley Center

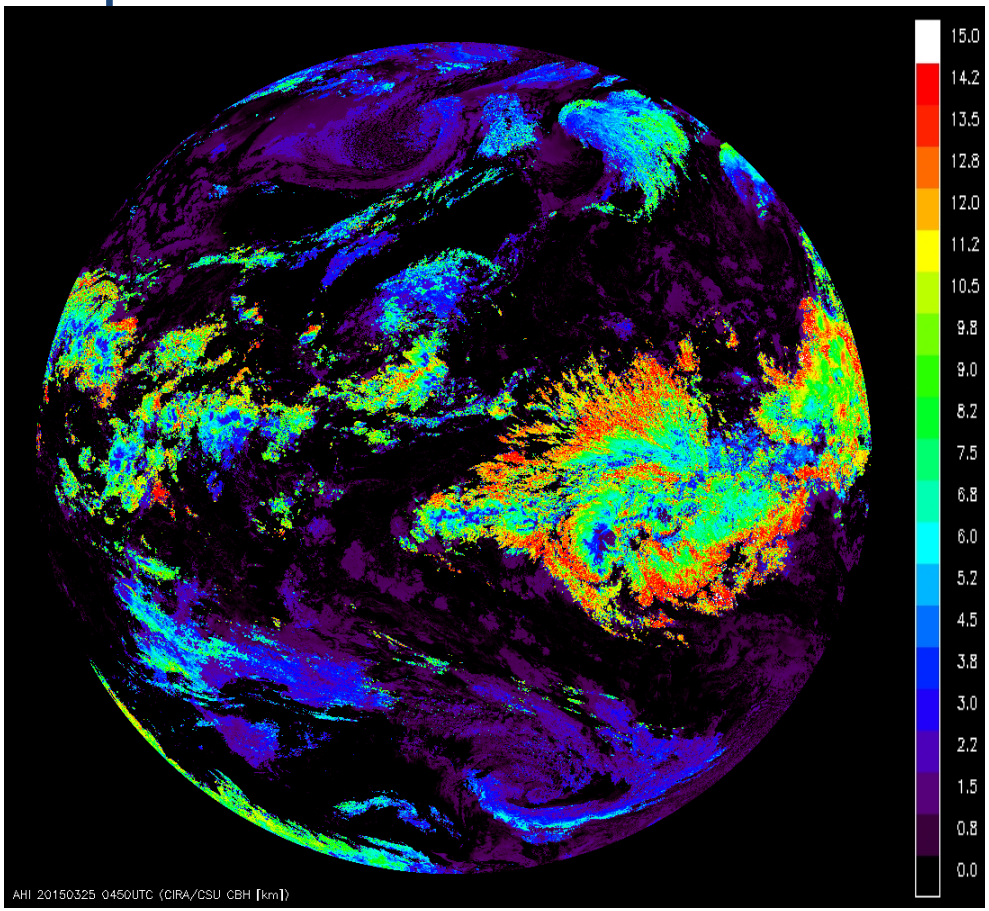
Apply to geostationary satellites (II)

Himawari-8 AHI -> *for the future GOES-R ABI*

Sample CBHs at 0450 UTC on 25 March 2015



AHI 11μm TBs (190-300 K)

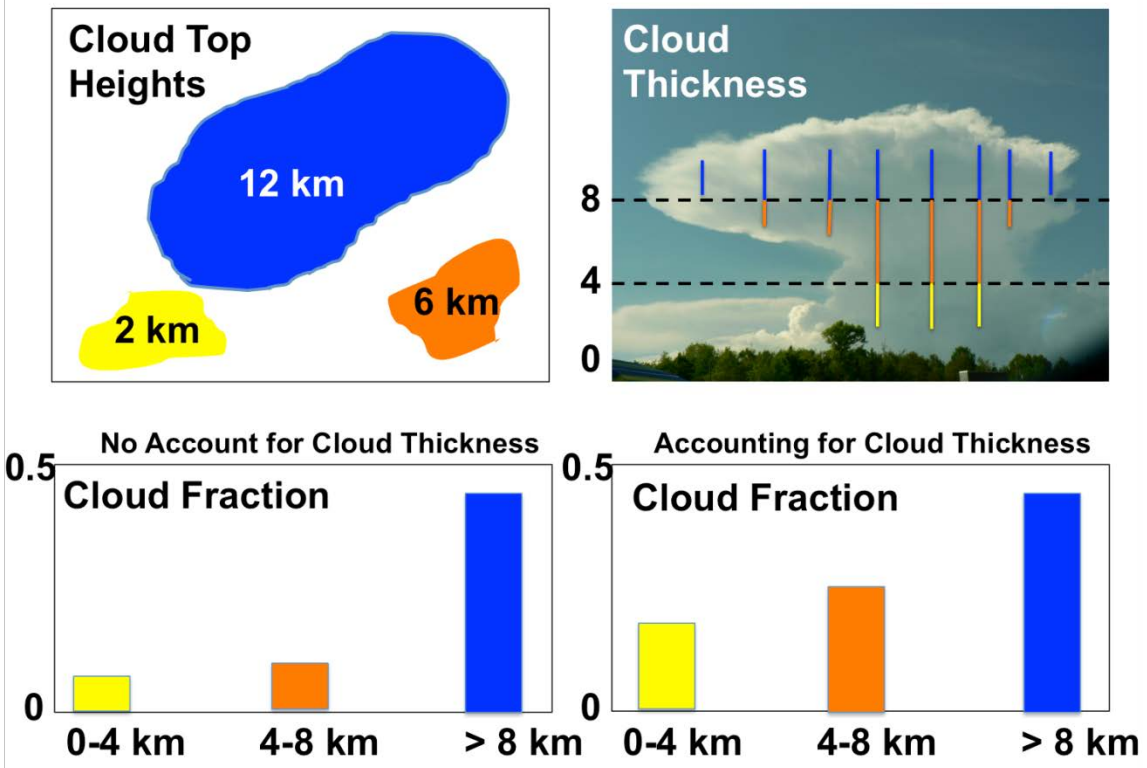


CIRA CBH (km)

Cut the edge

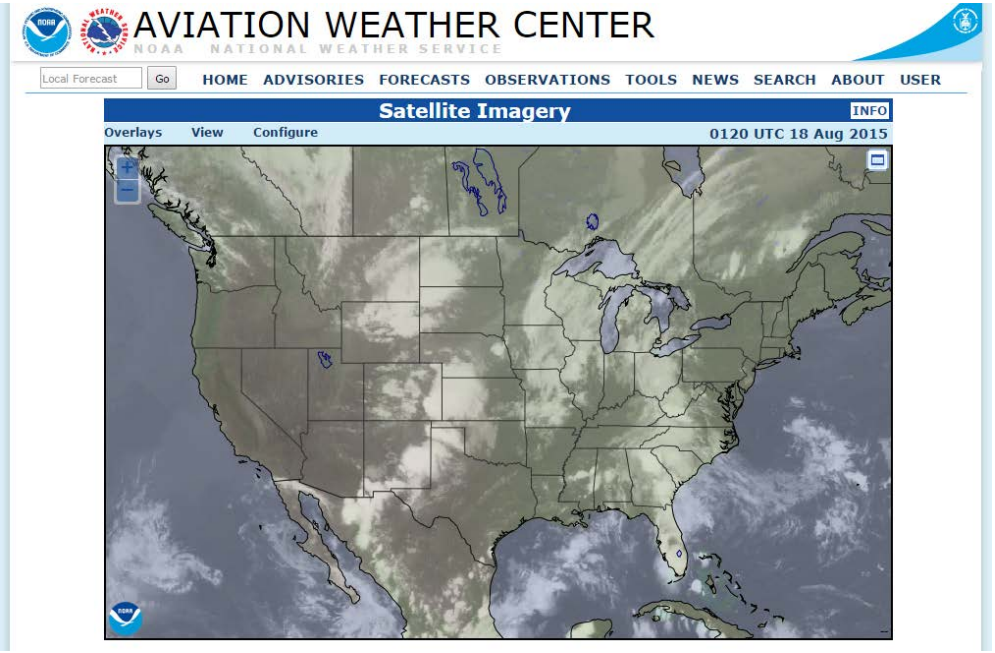
For Cloud Cover Layer improvement

- Once the optimized cloud base height estimate has been established and validated, we can use it for improved CCL products.
- **The cloud geometric thickness information allows for a pseudo-three-dimensional cloud field which can be used to estimate cloud fractions at lower levels below CTH.**
- Coupling the information with cloud classification and NWP temperature profiles would assist in providing useful parameters with regard to CCL retrievals.

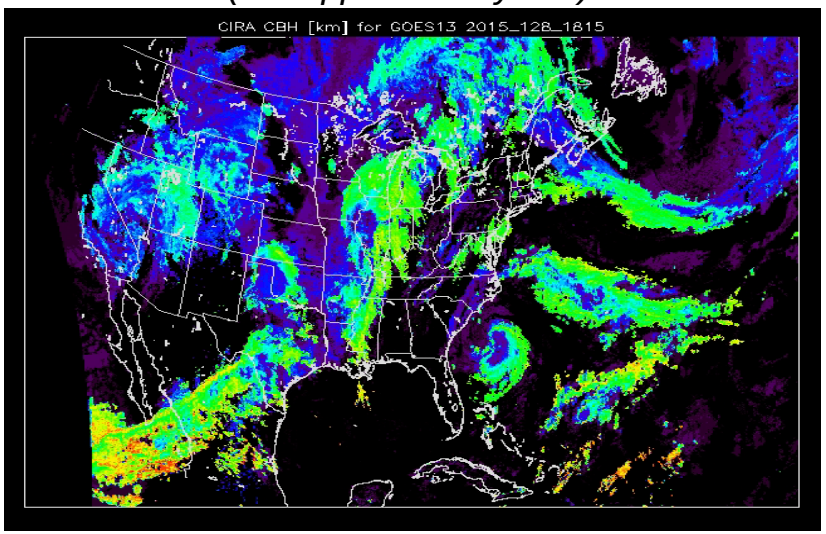


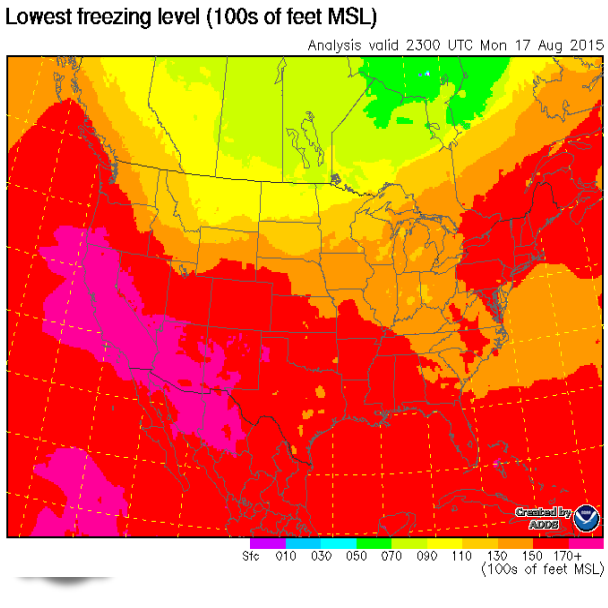
Conceptual illustration of how cloud geometric thickness information can be used to modulate the layered cloud fraction (high/mid/low) by introducing additional cloud coverage at lower (unobserved via satellite) levels of the profile.

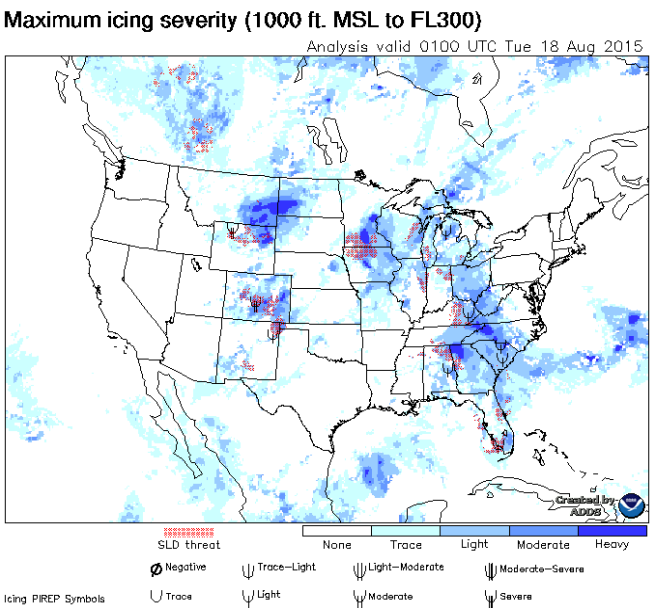
For potential users …

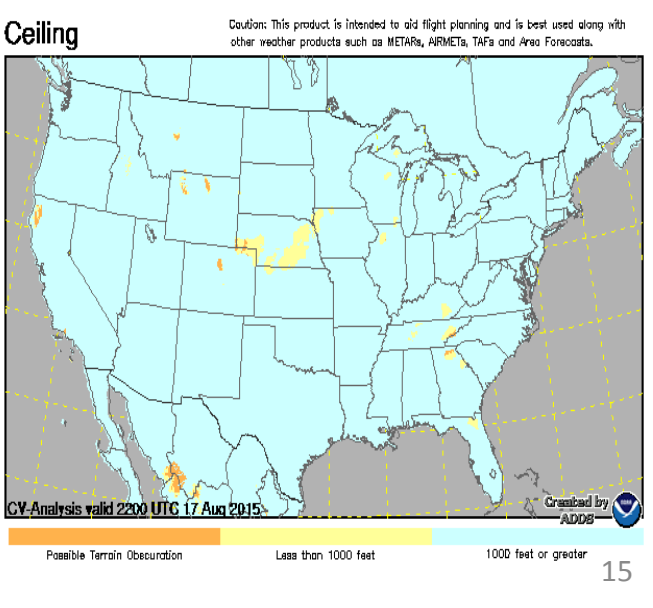


Satellite CBH of the upper-most layer and CCL
(as supplementary info)









Summary

- Retrieving CBH is difficult. Our evaluation showed the IDPS CBH environmental data record provided only marginal skill.
  - Cloud Top Height and Cloud type errors significantly impact CBH.
- **CIRA developed a new statistical CBH algorithm constrained by CTH and CWP using CloudSat/CAIPSO and Aqua MODIS data.** (*Now part of the CLAVR-x system*)
- **The enterprise CBH algorithm outperforms** the other algorithms particularly when CTH is “within spec”.
  - Work in progress is exploring alternative fits for the optimized CBH retrievals such as a higher order polynomials to improve thick cloud base.
  - Validation efforts are ongoing for an extended CloudSat matchup period (Jan-May 2015) including nighttime CBH performance test and comparisons with CALIPSO for thin cirrus.
- Once the optimized cloud base height estimate has been established and validated, we can leverage it to address forecaster needs for improved Cloud Cover Layer products.

Thank you!