ECM Status and Planning

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JPSS ECM Cloud Team

Background

- The ECM will replace the VCM for JPSS-1 EDR products
  - The ECM is running operationally today on NDE
    - Became operational, that is available on PDA, 5 July 2017
  - There is no 30-day spin up needed as with the VCM
- The most significant difference between them is that the ECM is not “tuned”, but “trained”
  - As such, any Look-up Table (LUT) updates will take longer to determine, test, and implement than tuning the VCM
    - Next ECM LUT update is scheduled to be implemented in Jan 2018
- However, similar to the SNPP, significant interaction is needed between the cloud mask team and dependent users of the ECM

Cloud Mask Cal/Val Plan

- The Cloud Mask Cal/Val plan was completed in July of 2015 as part of STARs overall commitment to finishing J1 Cal/Val plans by the end of 2015
  - It has not been modified since then
- The schedule in 2015 had to leave open the possibility that validation could occur with either the VCM or ECM
  - They have different paradigms even though the methods to validate either one are the same
- The Cloud Mask is not a KPP, however the need to accelerate its validation remains the same as with SNPP
  - Numerous dependent downstream products need the performance of the ECM sufficiently described earlier rather than later
  - Although the expectation is the ECM will perform similarly between SNPP and JPSS-1, this still has to be shown
  - Schedule needs to account for ECM update in January 2018
    - New 2-Dimensional map of prior values for cases of limited cloud detection tests (e.g. nighttime snow)
    - LUT update

ECM Cal/Val Schedule Adjustments

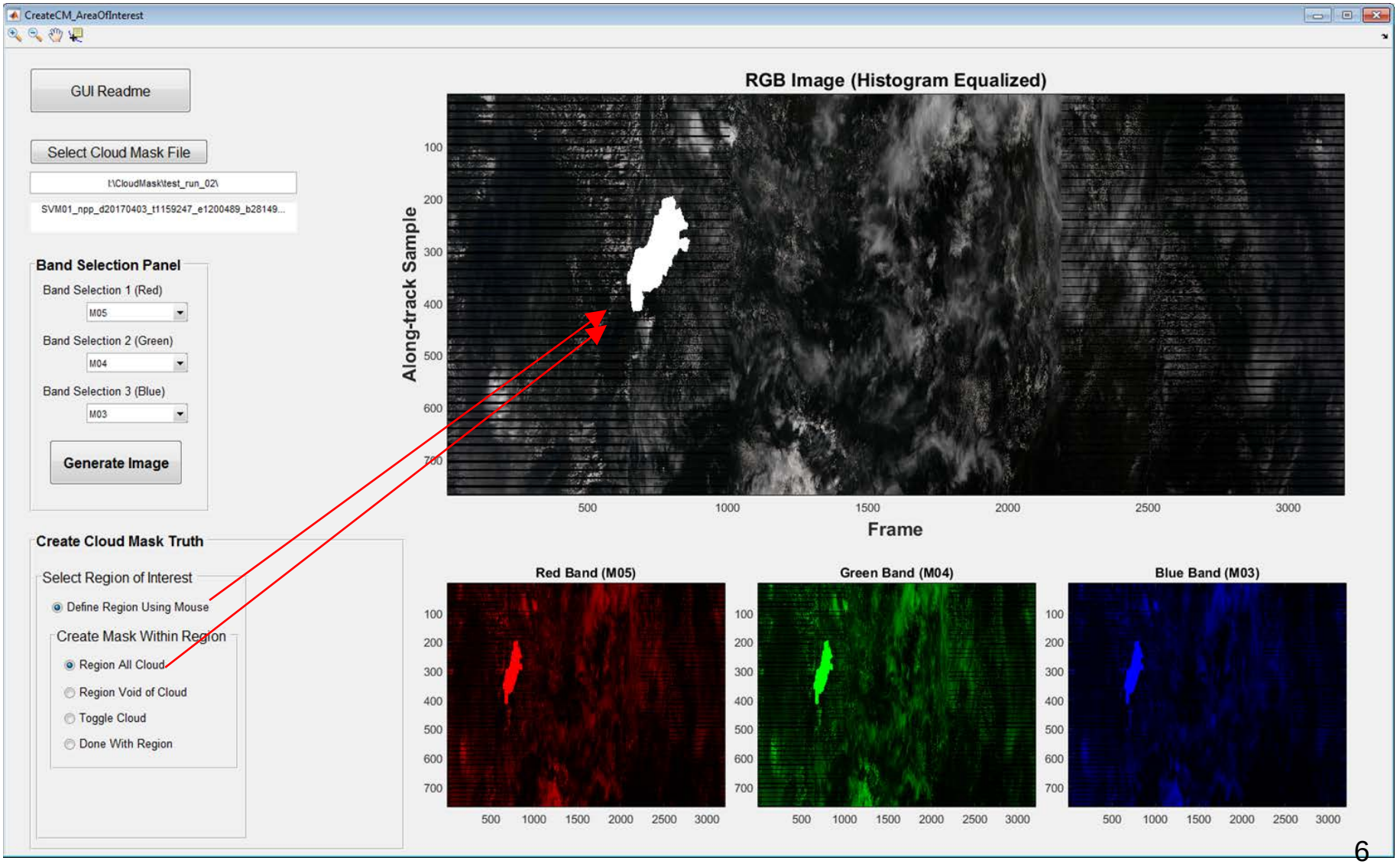
- The current “official” Cloud Mask Cal/Val plan contains the following schedule for the various phases of validation
  - Beta -> 8 months after launch
  - Provisional -> 9 months after launch
  - Validated -> 14 months after launch (one year of analyzed data)
- This schedule is not really tenable
  - 8 months for beta is too long; dependent users need quantitative insight into ECM performance before then
  - One month between beta and provisional not feasible, ECM updates will take longer than one month to test and implement
  - Amount of “truth” data may be more limited with likely loss of CALIPSO, impacts longer term timelines
- We propose the follow schedule be used for the ECM with JPSS-1 output
  - Beta -> 5 months after launch (mid-March assuming an October launch)
  - Provisional -> 9 months after launch
  - Validated -> 15 months after launch
- This schedule reflects the reality of the conditions under which the ECM will be validated
  - The shorter time frame for beta is necessary so dependent users understand better where the ECM is strong and where further work will be necessary
  - Schedule also accounts for LUT update in January
  - The larger amount of time for validated account for both the amount of time needed to retrain the ECM, if needed, and to allow for more data to validate with (account for the likely loss of CALIPSO)

Mitigating Loss of CALIPSO

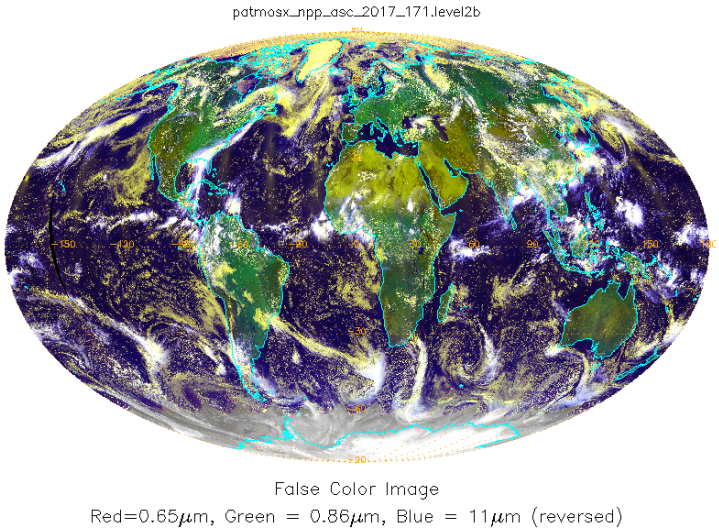
- The Cloud Mask validation plan for JPSS-1 contains a strong dependence on CALIPSO and Cloud Sat
  - Significant concern CALIPSO will soon no longer be useable
  - CloudSat already is daytime only
- Other methods, tools, and sources will be used to compensate
  - Comparisons with cloud masks derived by other methods and/or from other sensors (e.g. SNPP, MODIS) will be performed regardless of the availability of CALIPSO or CloudSat
    - This includes the VCM if it is still running on the IDPS
  - Ground sources such as ARM sites are viable
    - The amount of "truth" from these sources will be small and leave large spatial gaps
- Aerospace is developing a cloud mask manual analysis tool to supplement the available resources
  - The new tool allows for manual "truth" to be derived from any VIIRS granule, allowing for quantitative validation over any desired scene
  - It will also allow for quantitative evaluation for any ECM update
  - Target date to complete the tool is October/November 2017, before validation of the ECM would begin
  - Snapshots of the tool, which is still in development, are on the next two slides
  - The tool will also mimic the prior VCM visualization tool in that it will also allow a user to visualize individual cloud test output
    - Visualizing ECM output will be independent of the manual analysis tool such that the manual analysis can be performed without the analyst being aware of the ECM results

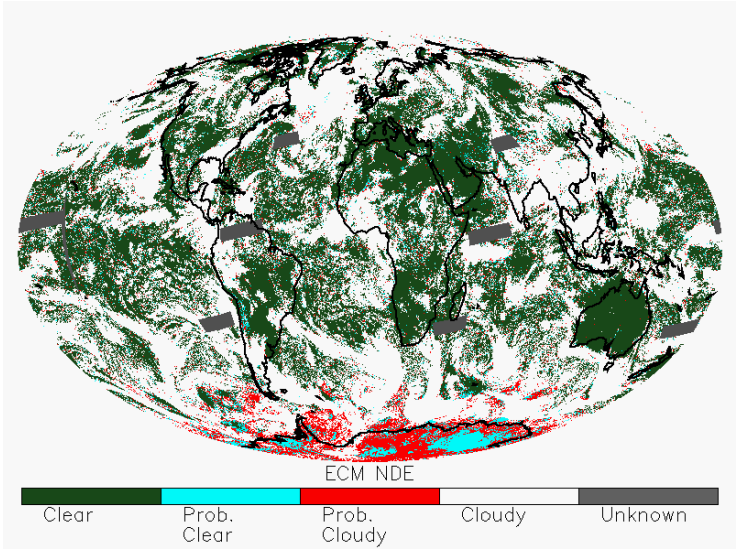
Sample of Manual Analysis Tool

Select Cloud Mask Region of Interest GUI



Operational ECM

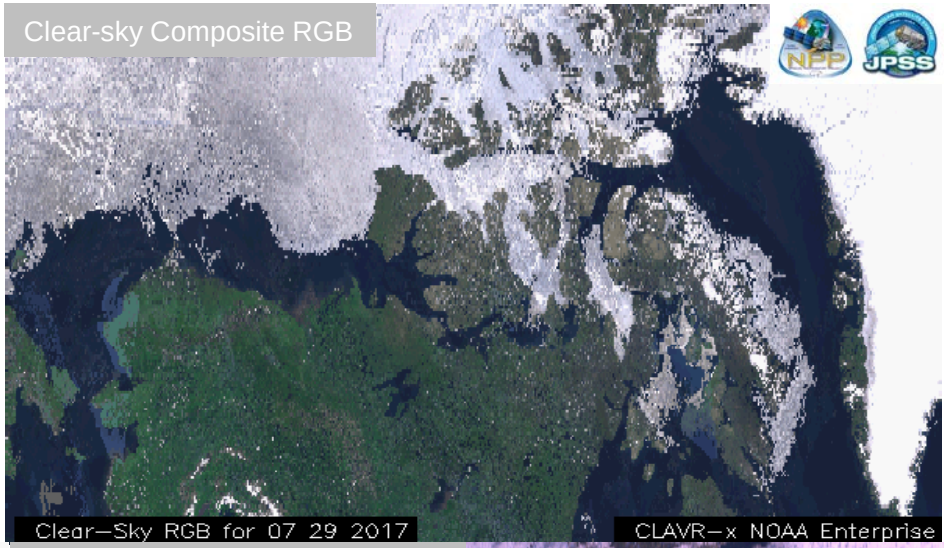


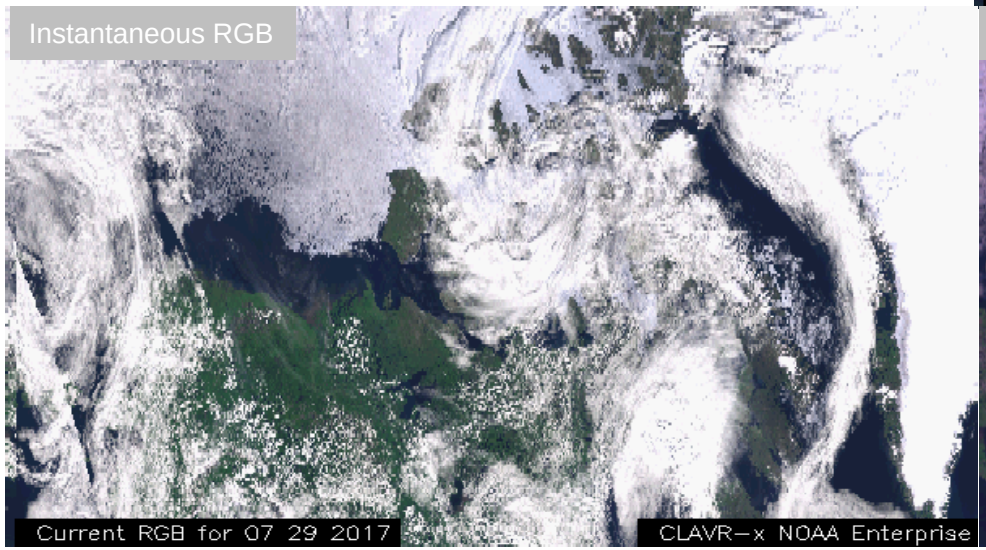


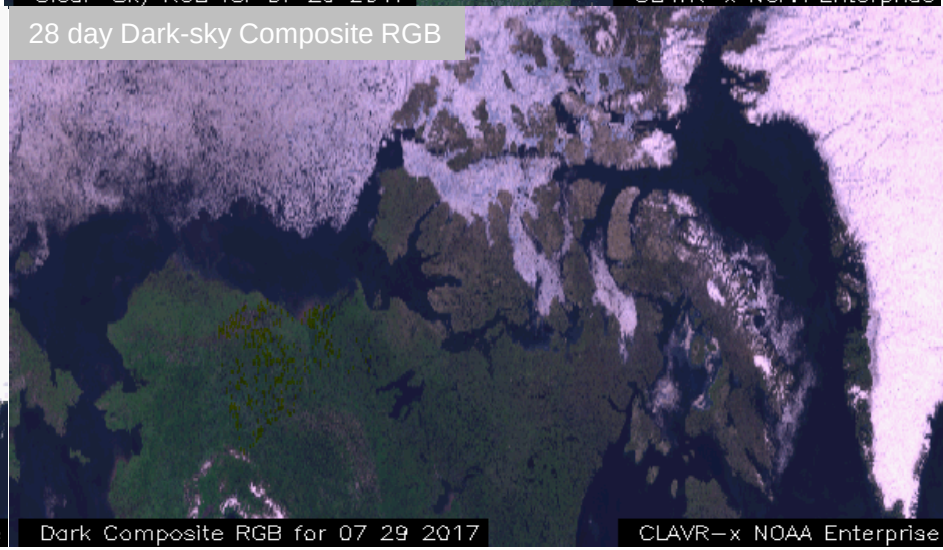
- ECM is running operationally on NDE since July 2017.
- ECM provides the following information:
  - ➢ 4-level Cloud Mask
  - ➢ Binary Cloud Mask
  - ➢ Cloud Mask Packed Bits
  - ➢ Cloud Probability
  - ➢ Smoke Mask
  - ➢ Fire Mask
  - ➢ Dust Mask
- Global images like these are available from the STAR JPSS EDR Monitoring Site. Imaging code will be transferred to STAR.

Clear-sky Composites of True Color VIIRS Imagery in the Northwest Passage

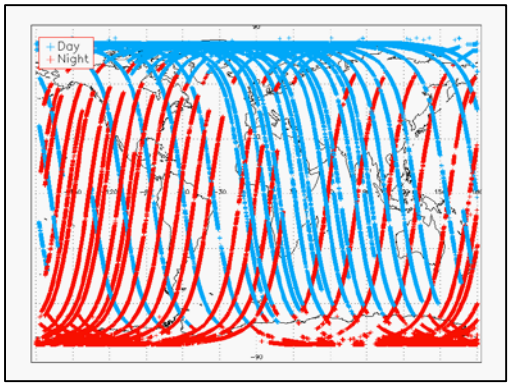
- Clear sky composites generated from NOAA Enterprise cloud mask.
- Composite updated every day. Data older than 2 weeks is removed.
- Dark-sky composite provides a nice validation of the clear-sky composite.
- ***Provides quantitative information to traditional RGB users.***







Operational ECM Evaluation



VIIRS-CALIOP collocation pixels
± 12 minutes, COD = 0.0 or COD > 0.5
2017-04-22, 2017-05-11 and 2017-06-20

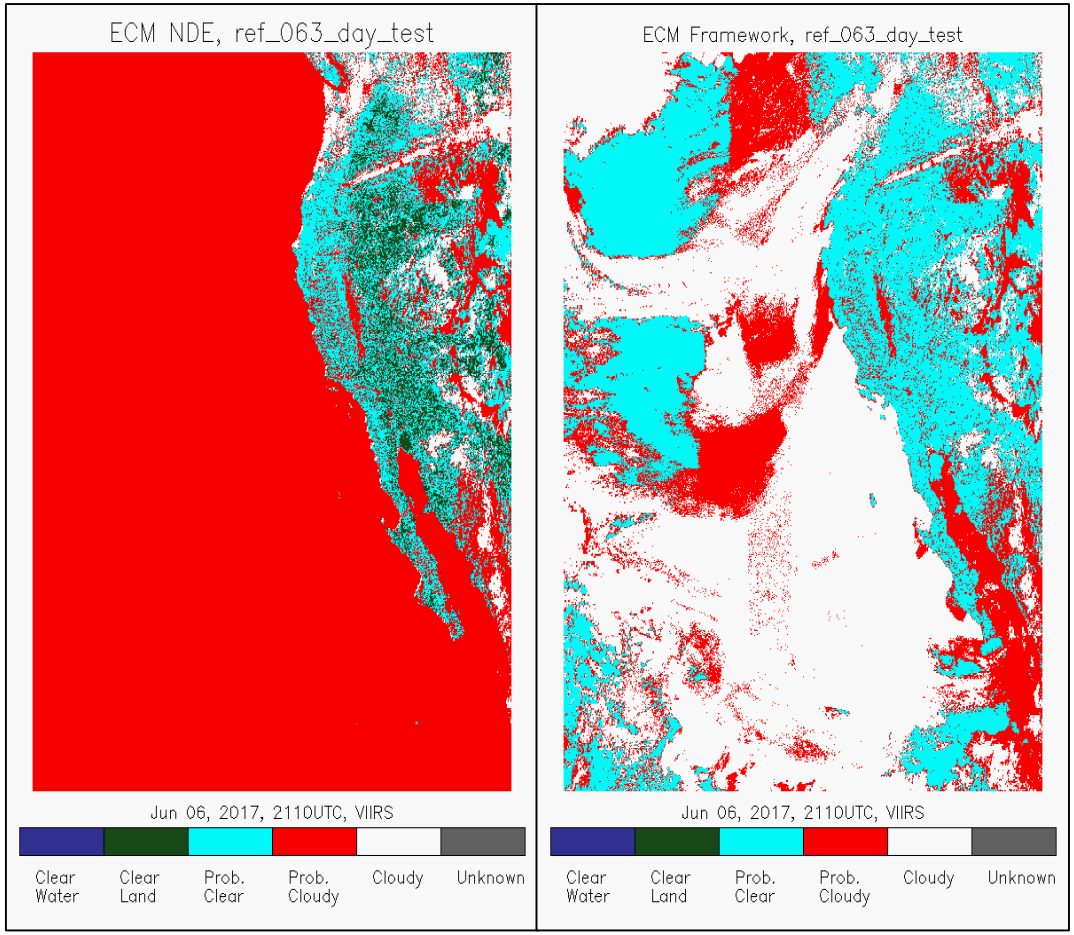
- To evaluate ECM performance 3 days with good CALIOP - VIIRS collocation were chosen.
- Statistics show that ECM over Ocean Day and Land Night do not quite meet spec, others do.
- A reason of lower performance are 2 bugs in the Static MODIS Albedo and impacts to the RTM (see next slide)

Sample Size	Cloud fraction				Required Detection	Probability of		
	CALIOP	VIIRS	Pr. Clear	Pr. Cloudy		Detection	False Detect.	Missed Cloud
Global, Ocean/Land, Day/Night, No Snow/Snow/Ice								
857300	0.680	0.635	0.082	0.098	-	0.878	0.039	0.083
Ocean, Day, Global, No Snow/Snow/Ice								
170485	0.683	0.664	0.017	0.018	0.940	0.914	0.033	0.052
Ocean, Night, Global, No Snow/Snow/Ice								
226368	0.685	0.611	0.052	0.091	0.850	0.883	0.021	0.095
Land, Day, Global, No Snow/Snow/Ice								
81174	0.539	0.495	0.021	0.018	0.900	0.908	0.024	0.068
Land, Night, Global, No Snow/Snow/Ice								
48581	0.523	0.406	0.048	0.033	0.880	0.878	0.003	0.120

ECM Updates: RTM and Albedo Fix

NDE Operational
Before the Fix

AIT Delivery Early 2017
After the Fix

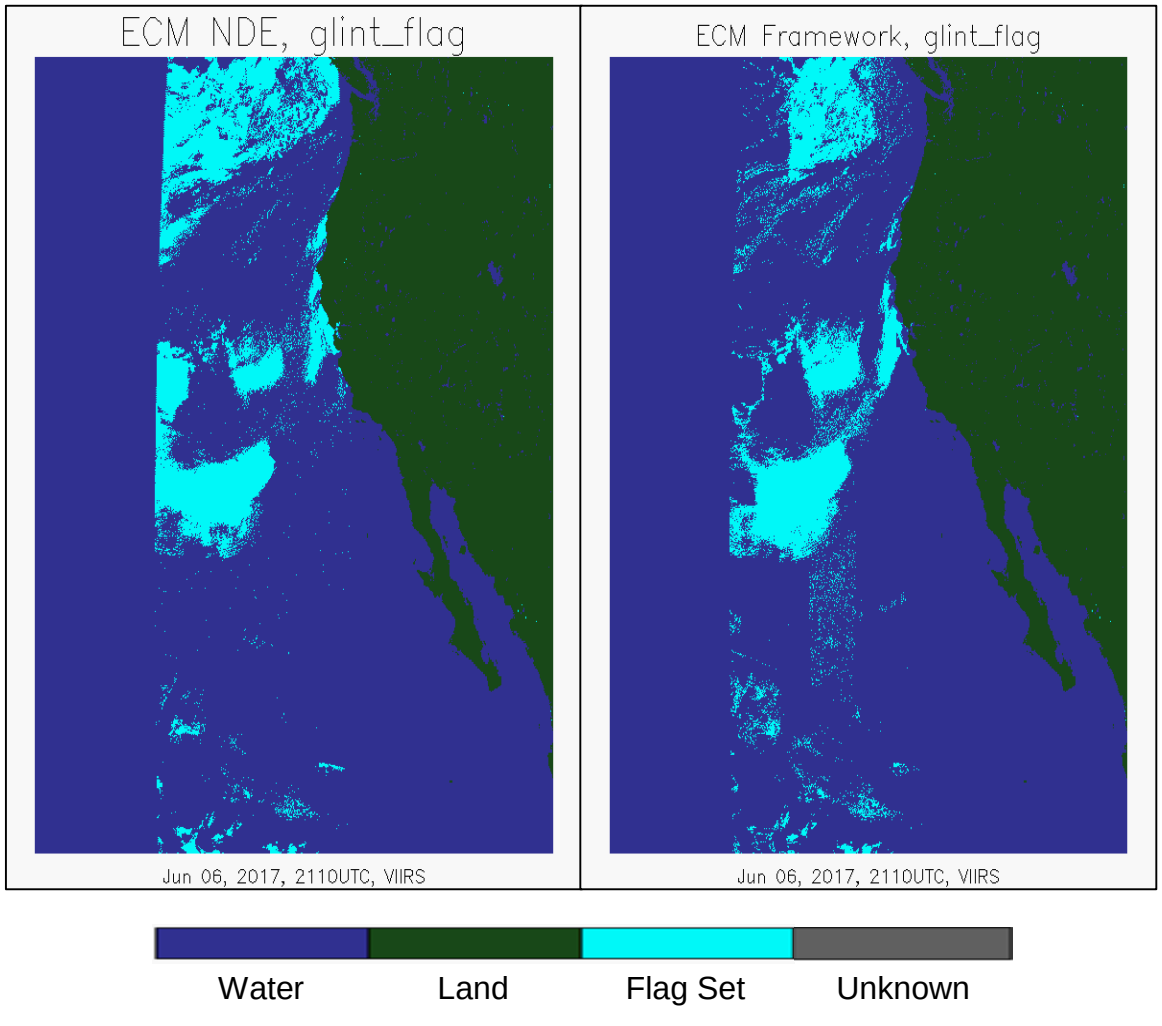


- NDE code didn't have an atmospheric correction for all pixels, because there was no RTM calculation.
- Also, Static Albedo file didn't have any value for water pixels. Hence, 0.65 μm Reflectance test was off over water.
- Both bugs are fixed and updated code delivered to NDE early 2017.

ECM Updates: Glint Logic Update

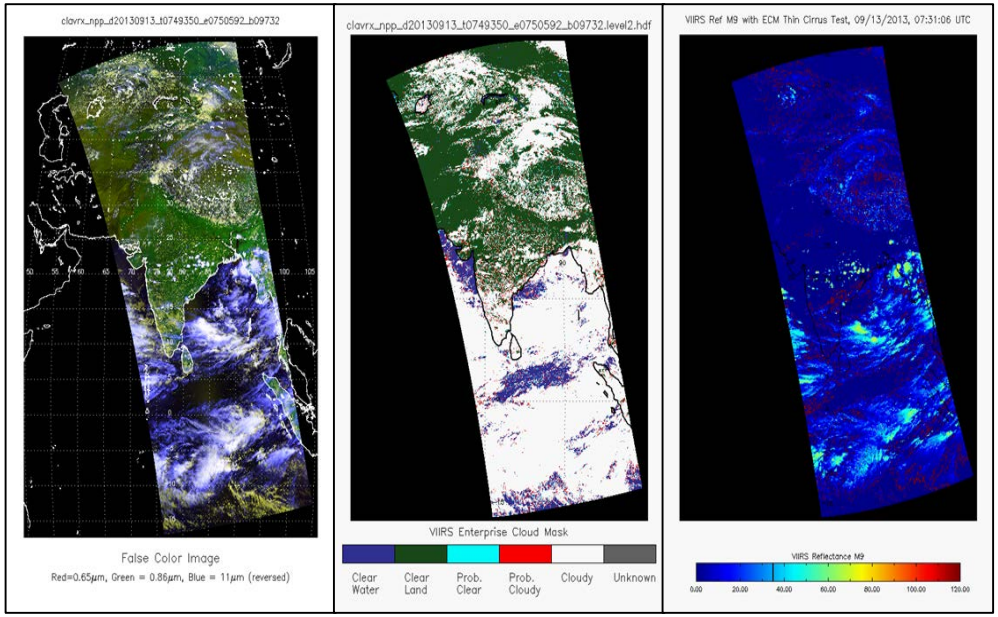
NDE Operational

AIT Delivery Early 2017



- Glint flag turns off several ECM tests. To improve performance over glint regions the logic of the Glint algorithm was revised. Hence, number of Glint pixels is reduced.
- The new algorithm logic was delivered to AIT at the beginning of 2017.

ECM Updates: Thin Cirrus Flag



RGB ECM M9 & Thin Cirrus

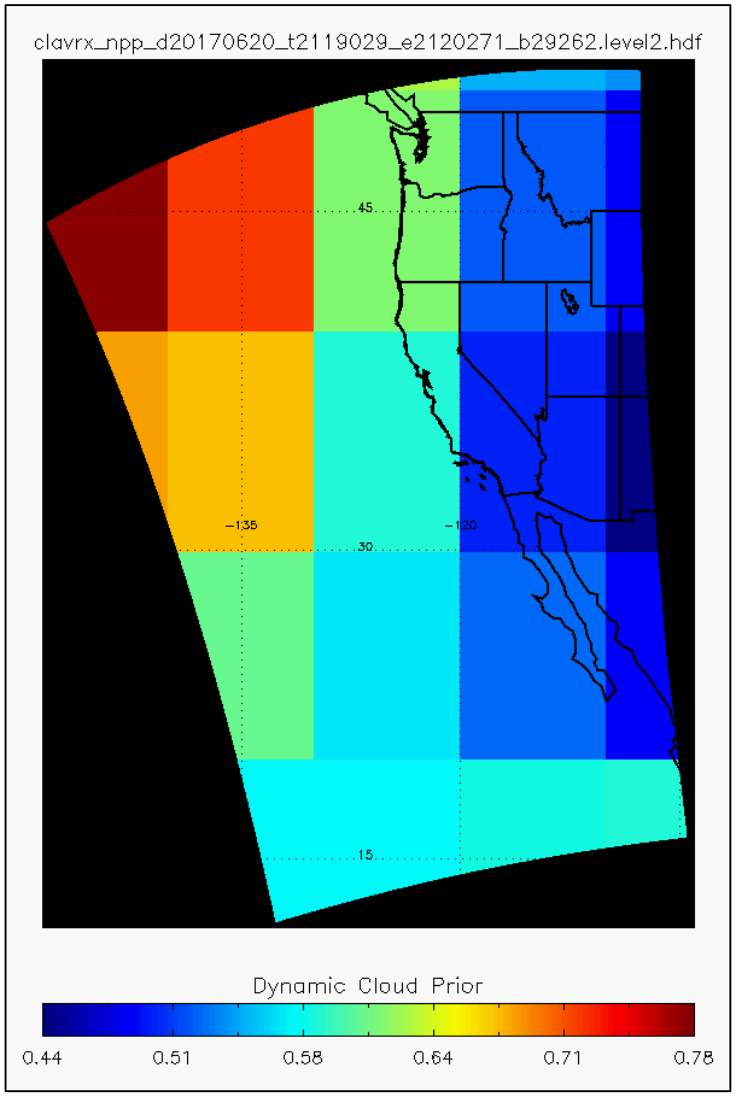
Byte	Bit	Flag Description Key	Result
2	0-2	Surface Type Used for Thresholds	001 = Deep Ocean 010 = Shallow Water 011 = Land 100 = Snow 101 = Arctic 110 = Antarctic + Greenland 111 = Desert
	3	Thin Cirrus Test	0 = Clear 1 = Cloudy
	4-5	BT 11 – 11 μm Thermal Test	00 = Clear 01 = Probably Clear 10 = Probably Cloudy 11 = Cloudy
	6-7	RTCT – Relative Thermal Contrast Test	00 = Clear 01 = Probably Clear 10 = Probably Cloudy 11 = Cloudy

Position of the Thin Cirrus Test Bit in the ECM Packed Bits

- ECM users expressed an interest in Thin Cirrus information, similar to provided by the IDPS VIIRS Cloud Mask (VCM).
- ECM team developed the Thin Cirrus algorithm, which gives similar results as VCM.
- The result is saved at the ECM Packed Bits.
- Delivered to AIT in 2016.

http://cimss.ssec.wisc.edu/patmosx/documents/Cloud_Mask_Enterprise_ATBD_v1.2_2016.pdf

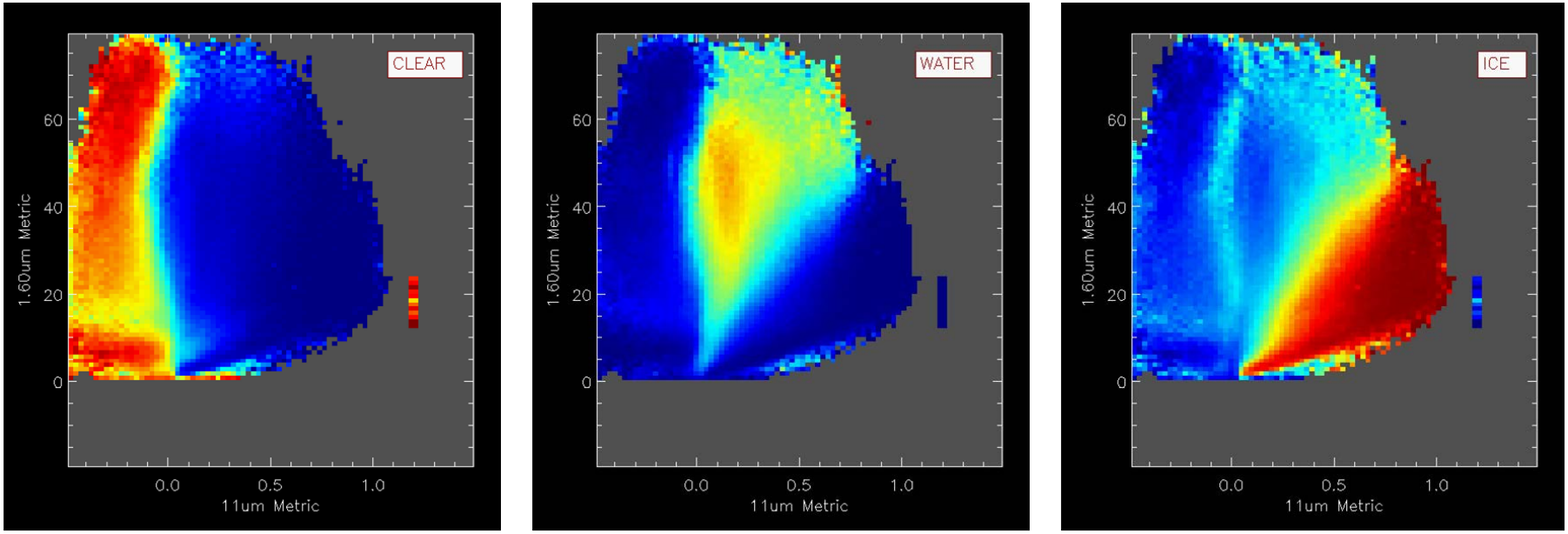
ECM Updates: Dynamic Cloud Prior



- In Bayesian ECM calculation a Prior Probability Distribution (simply Prior) indicates probability of cloud before any calculation.
- To increase ECM performance a Dynamic Cloud Prior is calculated based on VIIRS - CALIOP collocation data separately for 10x10 degree boxes, and each month of a year.
- Delivered to AIT in 2016.

ECM Updates: 2D Classifiers

- Several combinations of 2D classifiers should increase performance of cloud detection over currently used 1D classifiers:
  - ➢ 11 μm Tropopause Emissivity vs 11 μm BT Standard Deviation,
  - ➢ Day 11 μm Tropopause Emissivity vs 1.6 μm Reflectance,
  - ➢ Day 11 μm Tropopause Emissivity vs 3.75 μm Reflectance,
  - ➢ Night 11 μm Tropopause Emissivity vs 3.75 μm BT.
- Planning to deliver to AIT in Fall 2017



2D Classifier: 11 micron Tropopause Emissivity and 1.6 micron Reflectance

ECM Updates: NEW LUT

Algorithm	Sample Size	Cloud fraction				Required Detection	Probability of		
		CALIOP	VIIRS	Pr. Clear	Pr. Cloudy		Detection	False Detect.	Missed Cloud
	Global, Ocean/Land, Day/Night, No Snow/Snow/Ice								
ECM NDE	620281	0.667	0.604	0.087	0.045	-	0.880	0.029	0.091
FW OLD LUT	620281	0.668	0.621	0.090	0.046	-	0.873	0.055	0.072
FW NEW LUT	620281	0.668	0.638	0.140	0.074	-	0.895	0.042	0.063
	Ocean, Day, Global, No Snow/Snow/Ice								
ECM NDE	132151	0.659	0.649	0.013	0.007	0.940	0.930	0.030	0.040
FW OLD LUT	132151	0.657	0.644	0.020	0.009	0.940	0.943	0.022	0.035
FW NEW LUT	132151	0.657	0.629	0.033	0.017	0.940	0.953	0.025	0.022
	Ocean, Night, Global, No Snow/Snow/Ice								
ECM NDE	165140	0.705	0.686	0.048	0.029	0.850	0.917	0.032	0.051
FW OLD LUT	165140	0.706	0.673	0.082	0.058	0.850	0.925	0.031	0.044
FW NEW LUT	165140	0.706	0.695	0.201	0.073	0.850	0.936	0.027	0.037
	Land, Day, Global, No Snow/Snow/Ice								
ECM NDE	88247	0.512	0.426	0.019	0.011	0.900	0.895	0.014	0.091
FW OLD LUT	88247	0.512	0.474	0.052	0.022	0.900	0.900	0.041	0.059
FW NEW LUT	88247	0.512	0.438	0.059	0.025	0.900	0.913	0.026	0.061
	Land, Night, Global, No Snow/Snow/Ice								
ECM NDE	37577	0.693	0.604	0.081	0.031	0.880	0.902	0.004	0.093
FW OLD LUT	37577	0.694	0.575	0.097	0.040	0.880	0.896	0.017	0.097
FW NEW LUT	37577	0.694	0.609	0.314	0.090	0.880	0.908	0.028	0.063

ECM NDE - Operational ECM NDE
FW OLD LUT - Framework ECM with current operational LUT
FW NEW LUT - Framework ECM with the new LUT

* The reason of ECM NDE not meeting specs (red numbers) was discussed previously (Slide 9).

- The current ECM LUT is based on the MODIS - CALIOP collocation data. The new LUT is calculated on the 1 year (2015) of VIIRS - CALIOP data.
- The new LUT gives around 1-2% improvement of ECM performance.
- This stats are calculated based on VIIRS - CALIOP data from 2015-08-15 and 2015-08-31.
- NEW LUT is delivered to AIT in August 2017, in ops in early 2018.

Conclusions

- The Cloud Mask plan was written in the summer of 2015 and assumes conditions no longer applicable to JPSS-1.
- The ECM Cal/Val plan will be adjusted accordingly.
  - The Cloud Mask team proposes to accelerate beta to support downstream dependent users in their validation efforts.
- In order to help address the loss of ”truth”, and to allow for quantitative analyses for entire granules, Aerospace is building a new tool that allows a “truth” to be developed via an experts’ analysis.
  - Key error for ocean day performance corrected.
  - Thin cirrus added specifically to address user concerns.
  - An important LUT update is delivered to AIT in August 2017, implementation expected in early 2018.

NOAA Satellite and Information Services
National Environmental Satellite, Data, and Information Service

IMSG
I.M. Systems Group, Inc.

CrIS Cloud Product From VIIRS collocation/Intergration processing

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Outline

- Physical Collocation Method
- LUT based Physical Collocation Method
- Problem and solution
- CrIS Cloud Product
- Conclusion

Physical Collocation Method

- The instrument observation(~ CrIS) is contributed by all the points within the effective field of view (EFOV).
- The physical collocation required the collocated observation and physical variables(~ Collocated VIIRS cloud product) have the same spatial and physical representivity
- The same spatial representivity required the collocated physical variable are from the same coverage area, (Same effective field of view (EFOV).
- The same physical representivity required the contribution weight of the individual point to the collocated physical variable are same.

CrIS/VIIRS Physical Collocation Processing

Data flow:

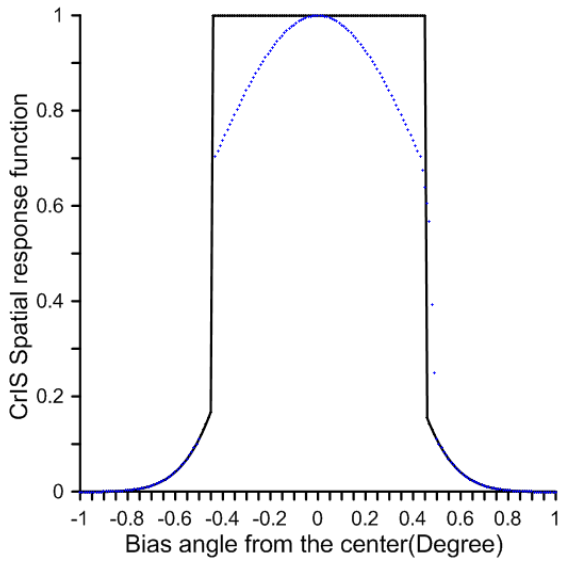
Step 1: The closing points collocation between different instrument is accomplished with observation geo-location information.(spatial Searching algorithms

Step 2: Identify all collocated observations. The closing VIIRS point is mapped to CrIS EFOV spatial response function(SRF) to get the contribution weight of the collocated points. The point with non zero weight will be collocated.(Input : Satellite position and attitude, observation geo-location, EFOV SRF)

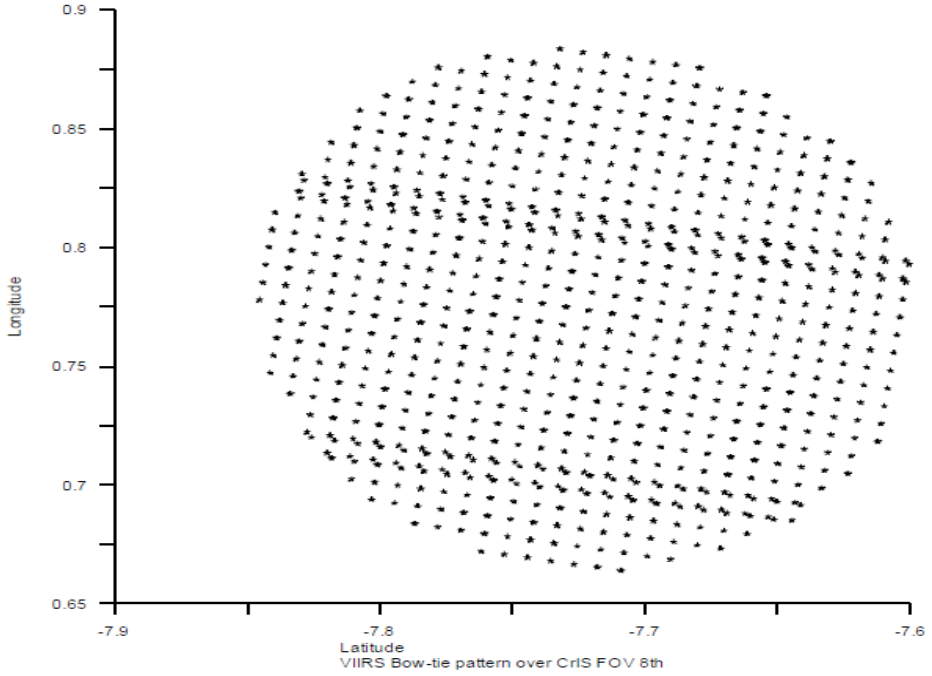
Step 3: Averaging/Integrate the collocated VIIRS point with/without the contribution weight.

Physical Collocation Method

In the CrIS/VIIRS collocation processing, the master instrument (CrIS) EFOV SRF is used to identify all collocated slaver observation(VIIRS) within the EFOV



CrIS EFOV SRF



VIIRS Collocation Colocation

LUT based Physical Collocation Method

Operational Requirement: In JPSS CrIS/VIIRS collocation operational processing, the processing speed is listed as the most critical requirement. The collocation scheme with the look up table(LUT) is selected.

POS: The LUT method significantly speed up the processing by applying the off-line calculated match-up LUT in the integration processing.

Condition: Given the relative position between the collocation observation from different observation system keep "Fixed", a pre-calculated LUT for the collocation can be used in the real time processing.

VIIRS ,CrIS instruments are aboard on the same observation platform and their relative position keep "fixed". LUT based Physical Collocation Method is selected.

The problem introduced by the of relative position variation need to be addressed when the LUT method is selected for collocation processing.

LUT based CrIS/VIIRS Physical Collocation Processing

Data flow:

Step 1: Identify all collocated observations. The collocated VIIRS point is identified with LUT. (Input : off line calculated LUT)

Step 2: Averaging/Integrate the collocated VIIRS point with/without the contribution weight.

POS:

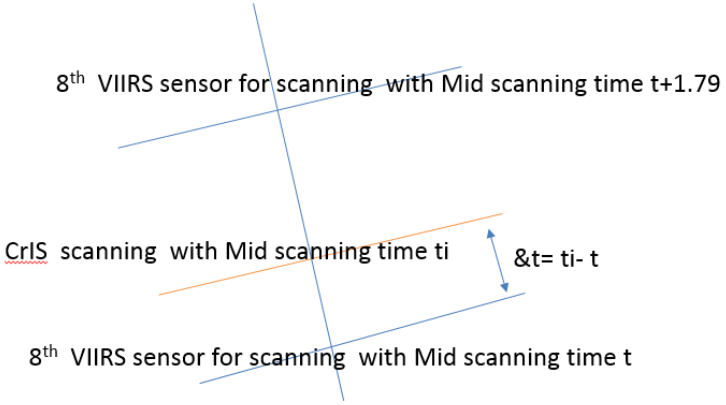
1: No time consuming calculation

2: EFOV SRF is applied

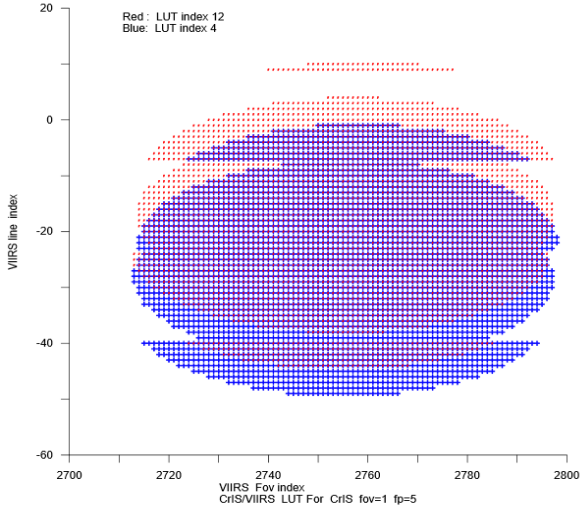
LUT based Physical Collocation Method

The LUTs for the collocation is trained with the real observation navigation data. Multiple tables are trained with the real collocated CrIS/VIIRS data with “different relative position” due to the scan mirror rotate period difference.

The collocation LUTs are trained at 16 even distributed t_{li} time point [0,1.784]. The time intervals is 0.113 second and the surface along track movement is about 0.75km. This is also the spatial resolution of the colocation LUT



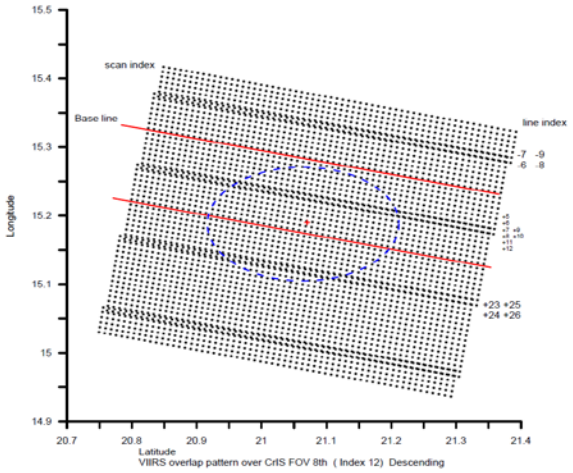
Multiple LUT Trainning

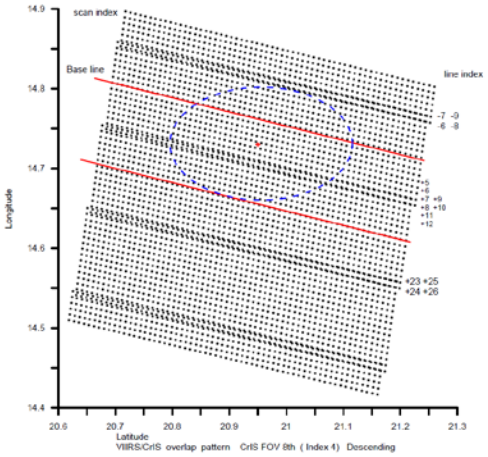


Problem: Fixed Relative position vs Different scan period

In CrIS/VIIRS collocation, The observation time difference in collocation processing should be equal or close enough to the observation time difference of the in collocation LUT training.

The solution is to use multiple LUTs according to the observation time difference. For the CrIS FOV, Multiple LUTs are trained with the overlapped CrIS/VIIRS data set with different time difference.

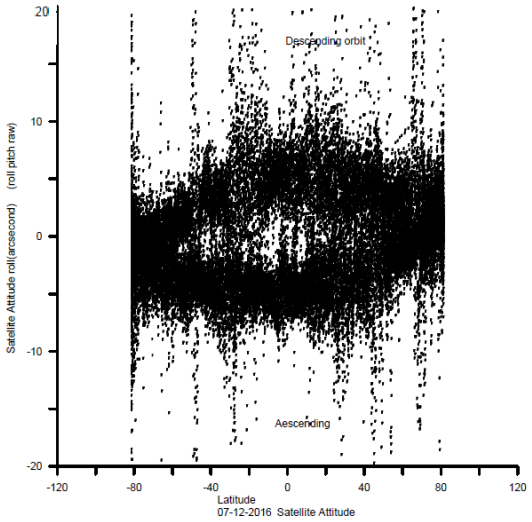




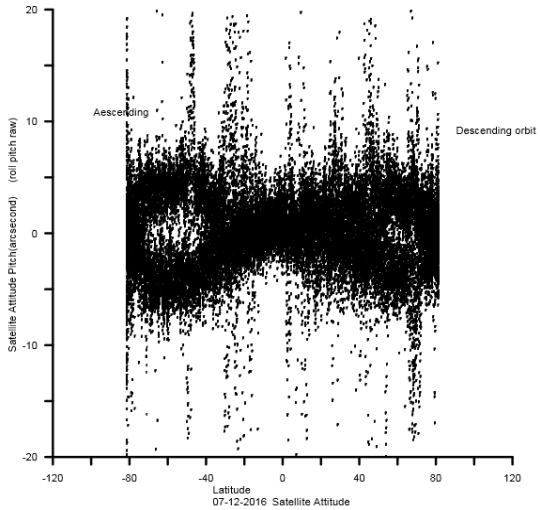
Problem: The relative position variation relating with satellite attitude

Spacecraft with momentum actuators suffer from attitude jitter and high frequency oscillations due to imbalance in the rotors of momentum actuators. Beside the attitude jitter, NPP satellite attitude also has the system variance pattern according to the latitude.

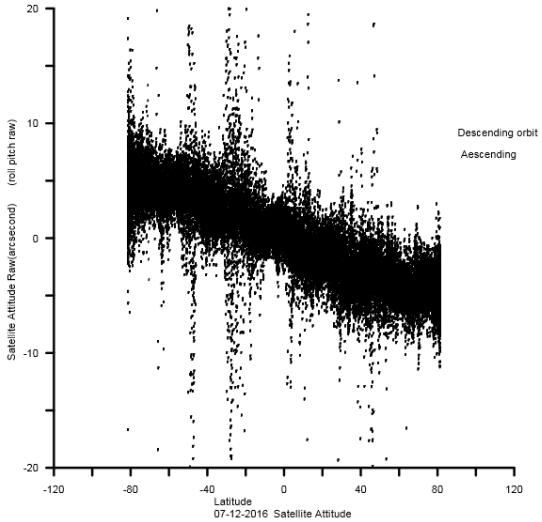
In CrIS/VIIRS collocation, The observation **satellite attitude** in collocation processing should has equal or close enough to the **satellite attitude** of the data used in collocation LUT training.



Roll



Pitch



Raw

Solution: The relative position variation relating with satellite attitude

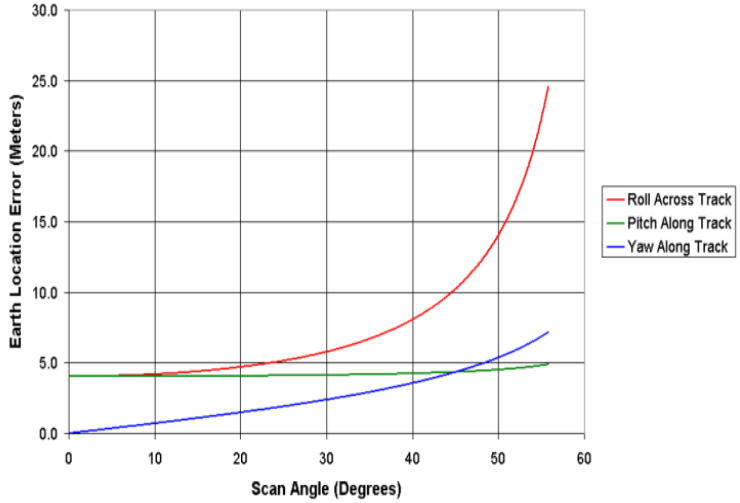
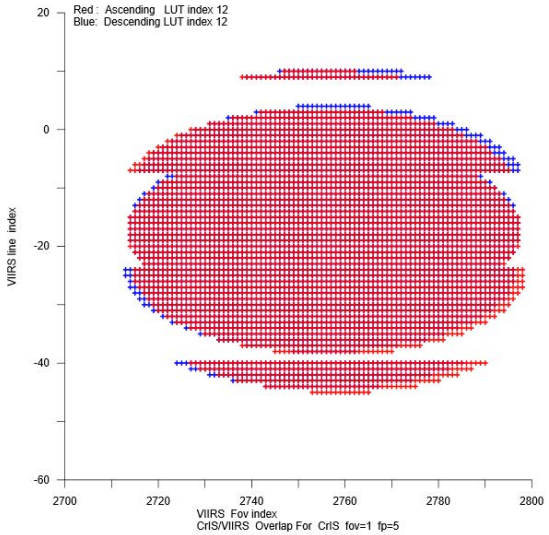
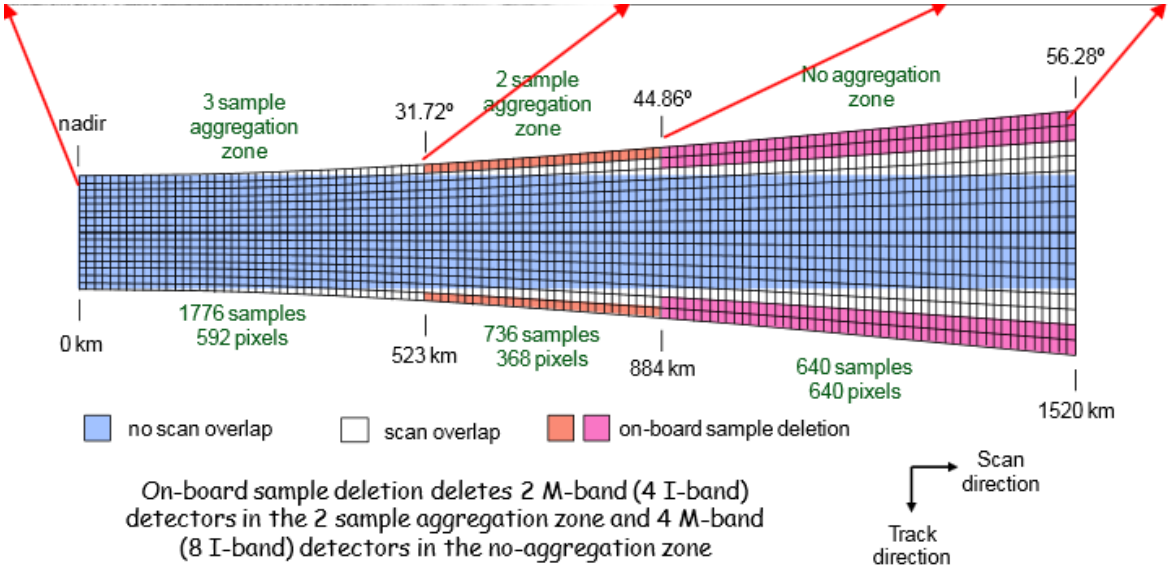


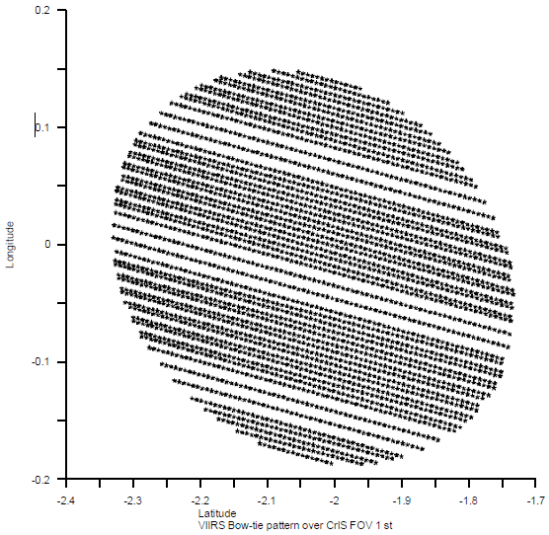
Figure 3.4-5: Earth Location Error (in meters) resulting from Instrument/Platform Pointing Error (in arcseconds) as a Function of Scan Angle



- Basing on the attitude effect and the attitude pattern, In present LUT collocation, the collocation LUT are trained separately for ascending and descend observation. The collocation LUT are trained independently with descending and ascend data covering the equator area.

Problem: VIIRS Bowtie Effect





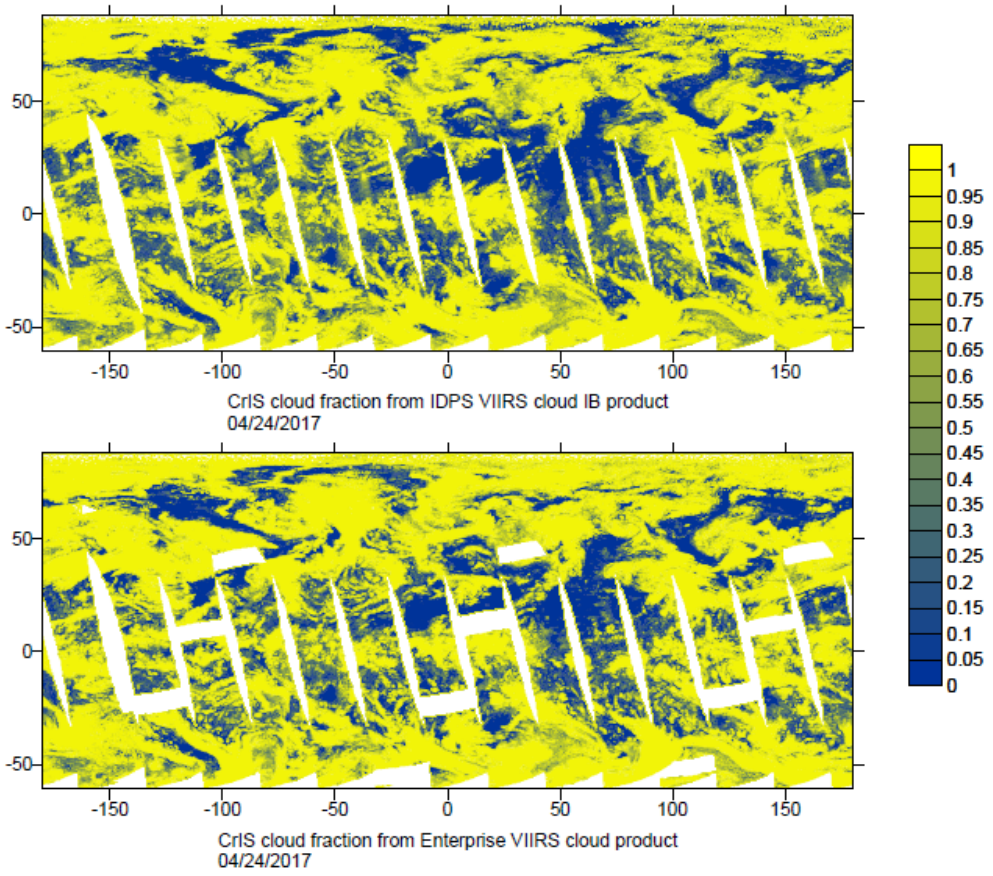
The VIIRS scan-to-scan overlapping lead to the un-uniformly distribution of the collocated VIIRS pixels.

To avoid problem introduced from the un-even slaver observation sampling problem, a two dimension grids G(X,Y) is used to selected the qualified slaver observation from the spatial overlapped VIIRS FOV.

Product

- The CrIS/VIIRS collocation/Integration processing provide CrIS FOV cloud fraction/ cloud top height information.
- CrIS FOV cloud data is generated from the collocated VIIRS cloud product(IDPS IB and EDR; Enterprise cloud product).
- The operational CrIS/VIIRS collocation processing provide the “real time” cloud input for CrIS retrieval processing. The processing speed is the most important requirement.
- The system transition: From IDPS VIIRS cloud to Enterprise VIIRS product

CrIS cloud fraction comparison in Ascending

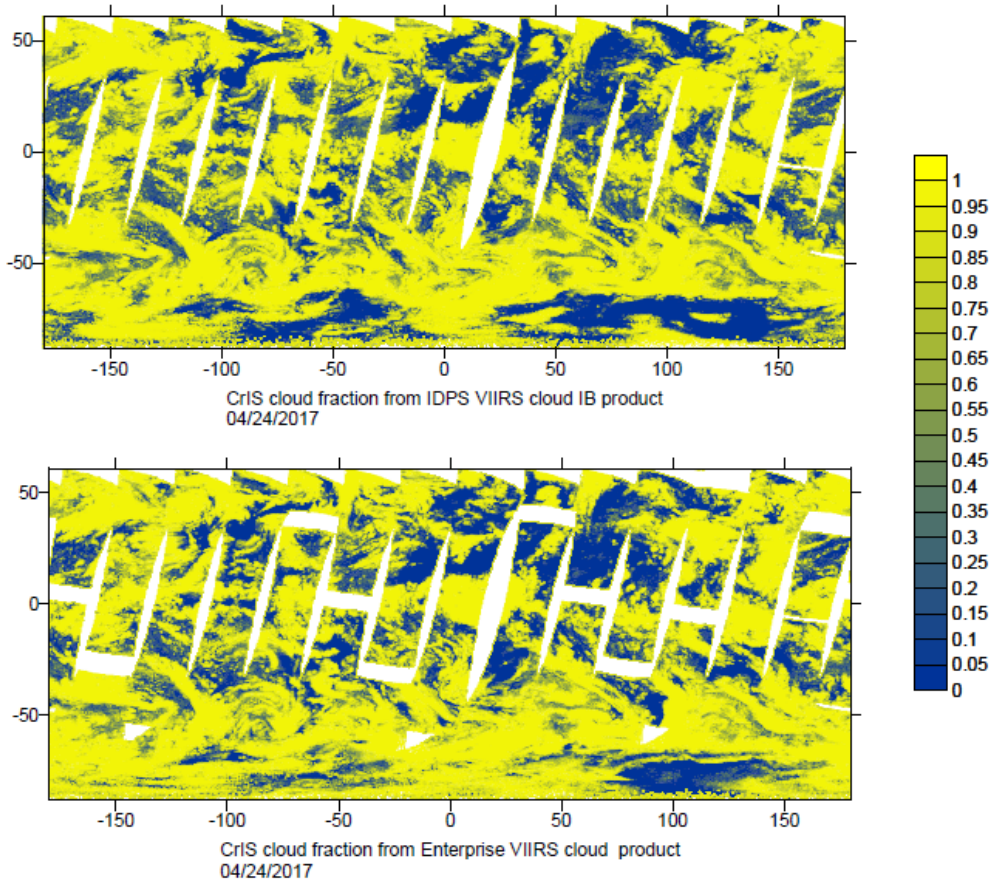


CrIS cloud fraction from Collocated IDPS product

Vs

CrIS cloud fraction from Collocated Enterprise product

CrIS cloud fraction comparison in Descending

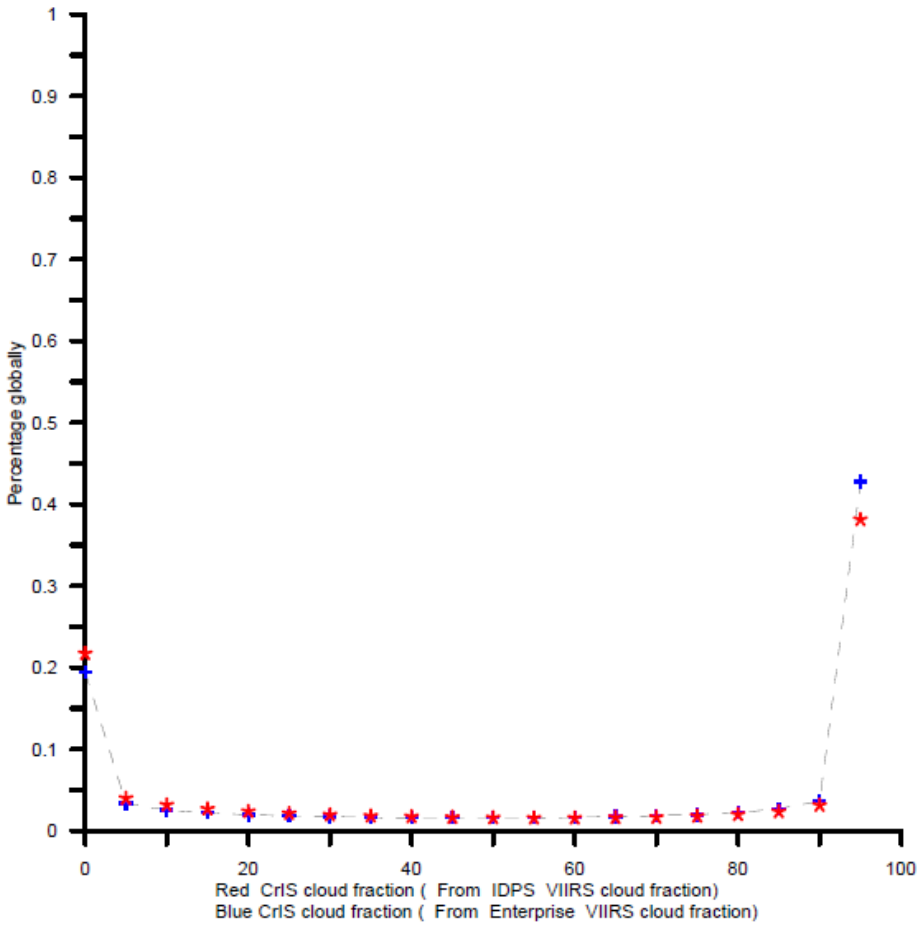


CrIS cloud fraction from Collocated IDPS product

Vs

CrIS cloud fraction from Collocated Enterprise product

CrIS cloud fraction comparison in Descending



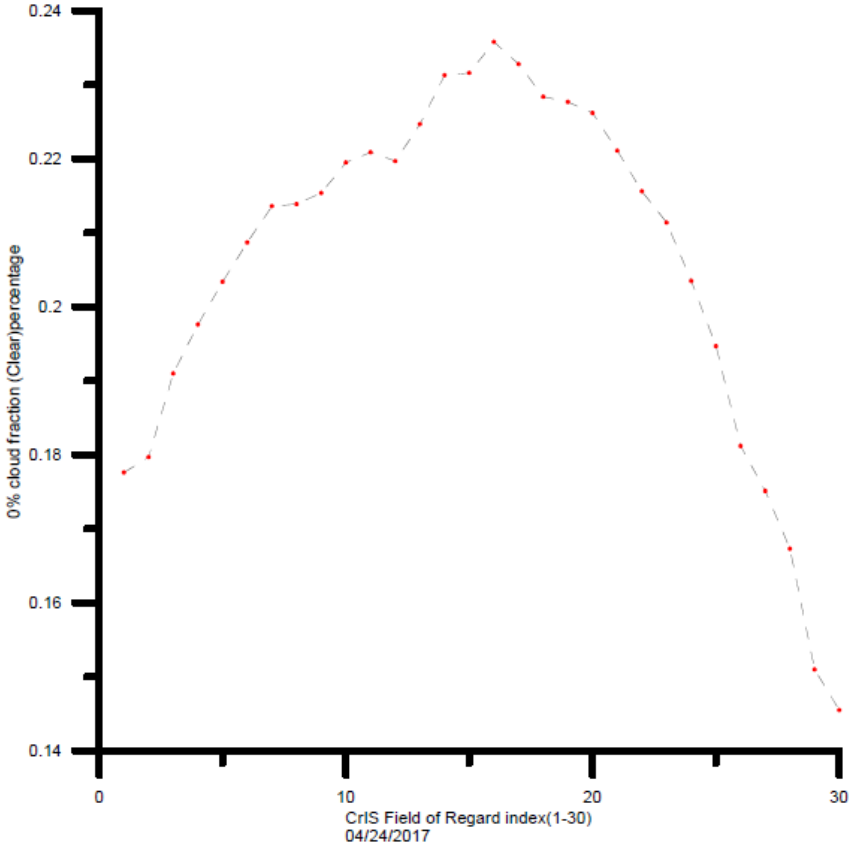
1: The collocated cloud fraction from IDPS and Enterprise are comparable.

2: Both own the double peak pattern

3: There are “more” cloud generated in JRR

There are some samples difference, the conclusion may not be correct. More analyzing are required.

CrIS Cloud Fraction vs Scanning Angle: Clear



The collocated cloud fraction vs Scanning angle.(Enterprise product)

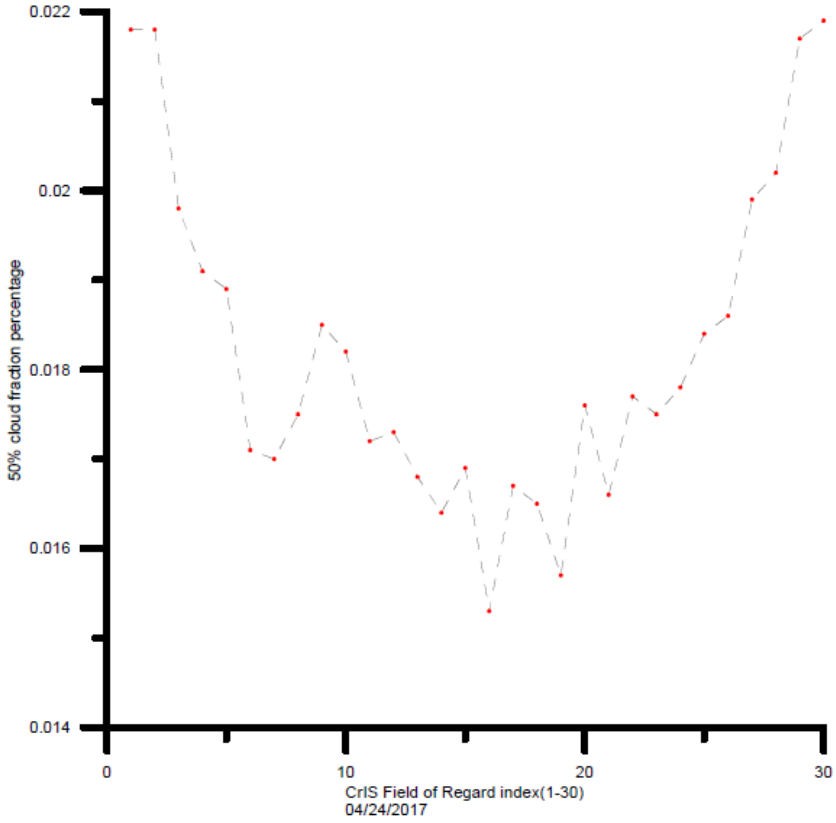
Clear case:

FOV size dependence (scanning angle related) ---symmetric

Scanning angle dependence ---asymmetric

Less clear case for for16-30

CrIS Cloud Fraction vs Scanning Angle: 50% cloud Fraction



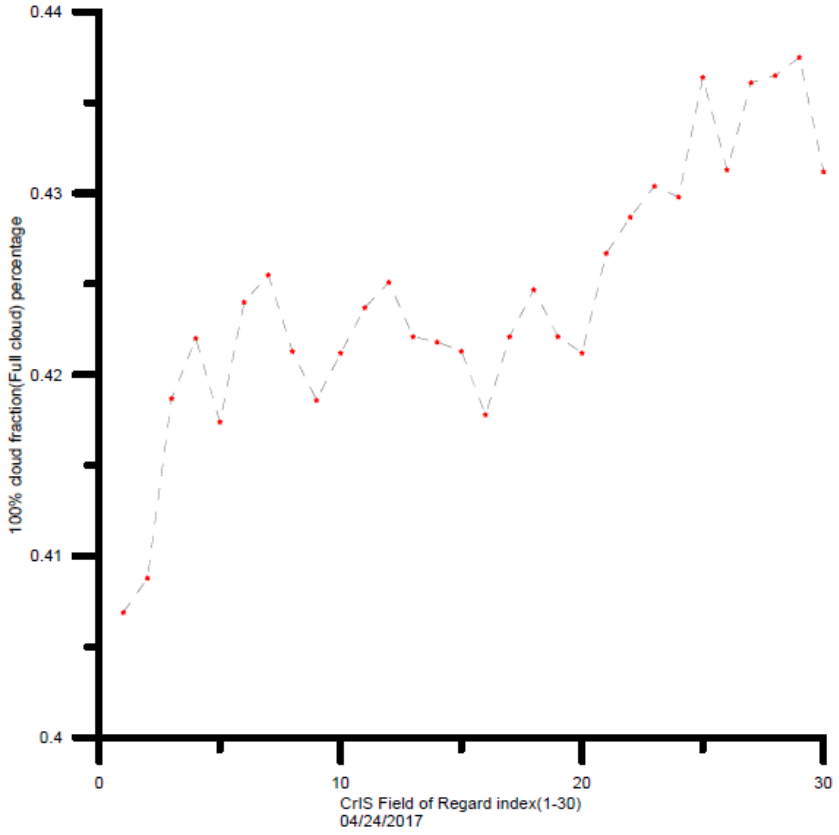
The collocated cloud fraction vs Scanning angle.(Enterprise product)

50% cover case:

FOV size dependence (scanning angle related) ---symmetric

Scanning size dependence for which is normal ---Asymmetric is not significant

CrIS Cloud Fraction vs Scanning Angle: Full cloud



The collocated cloud fraction vs Scanning angle.(Enterprise product)

Full cloud case:

FOV size dependence (scanning angle related) ---symmetric

Scanning size dependence for which is normal ---asymmetric

More cloud for for16-30

Conclusion

The CrIS/VIIRS collocation/Integration processing provide CrIS FOV cloud fraction/ cloud top height information.

CrIS FOV cloud data is generated from the collocated VIIRS cloud product(IDPS IB and EDR; Enterprise cloud product).

The operational CrIS/VIIRS collocation processing provide the “real time” cloud input for CrIS retrieval processing. The processing speed is the most important

requirement.

Initial Look at the VIIRS Cloud Products with CrIS for NCEP Data Assimilation in the GFS.

James Jung
Cooperative Institute for Meteorological Satellite Studies
University of Wisconsin, Madison

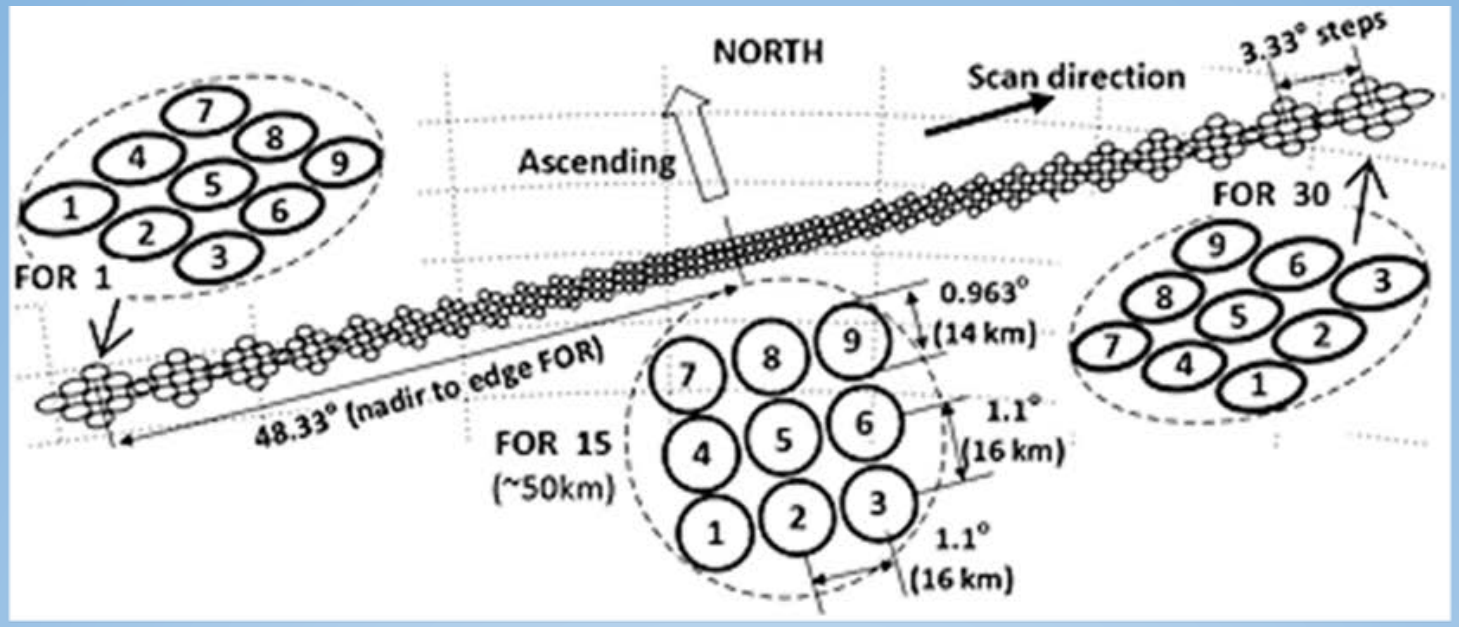
In Collaboration With

NCEP/EMC, NESDIS/JPSS, NESDIS/STAR, NESDIS/ASPB, NASA/NCCS



Background

- Enterprise VIIRS cloud information (cloud amount and height) was incorporated into the CrIS BUFR file ~ 1 May 2017
  - Developed by the NESDIS/ASPB cloud team (Andy Heidinger).
- Cloud amounts less than 1% are considered clear.
- Lowest cloud height used unless a clear field of view is found.
- If more than one clear field of view is found, the closest to the center of the thinning box is used.
- Increases observation counts and Improves “normal” error distribution
- If cloud information is missing, a warmest field of view derivative is used.
  - CrIS surface channel #501 is used

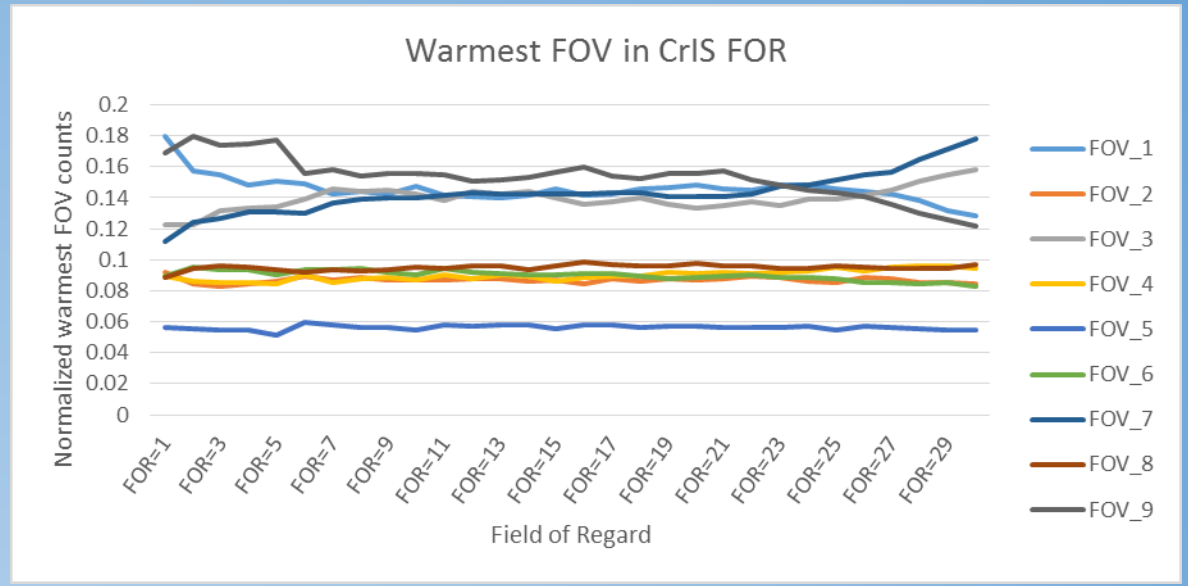


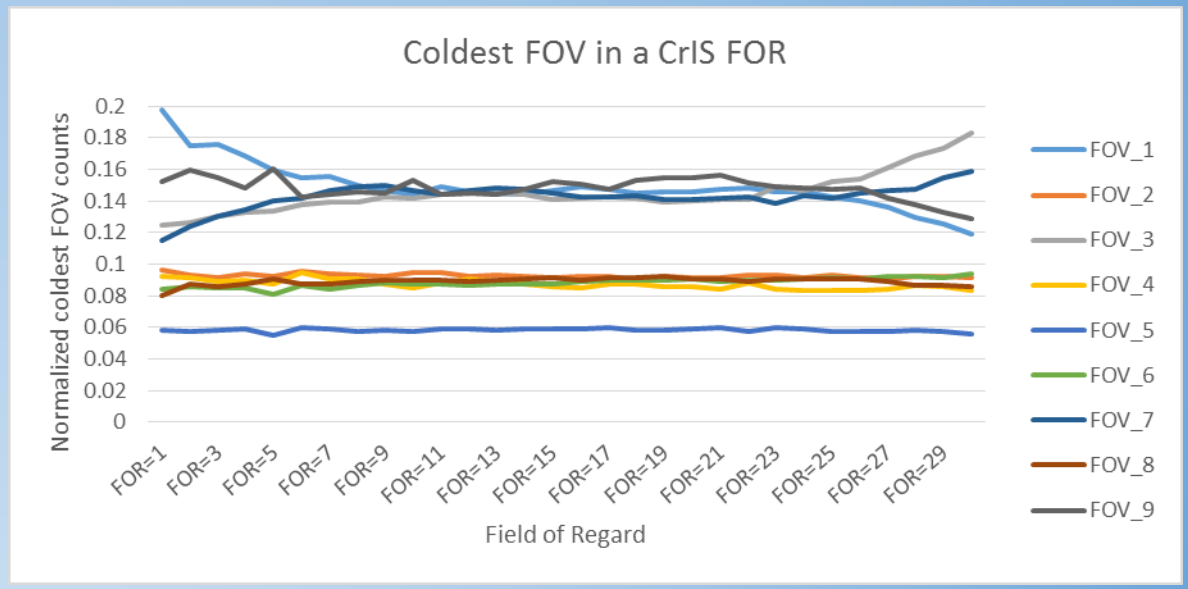
Journal of Geophysical Research: Atmospheres
Volume 118, Issue 22, pages 12,734-12,748, 25 NOV 2013 DOI: 10.1002/2013JD020344
http://onlinelibrary.wiley.com/doi/10.1002/2013JD020344/full#jgrd50972-fig-0003

Warmest Spot Statistics

Warmest field of view is biased toward the corners (1,3,7,9) and is consistent with AIRS.

Coldest field of view is also biased toward the corners. For CrIS-NPP, the warmest field of views tend to also be the coldest field of views with the same field of regard characteristics

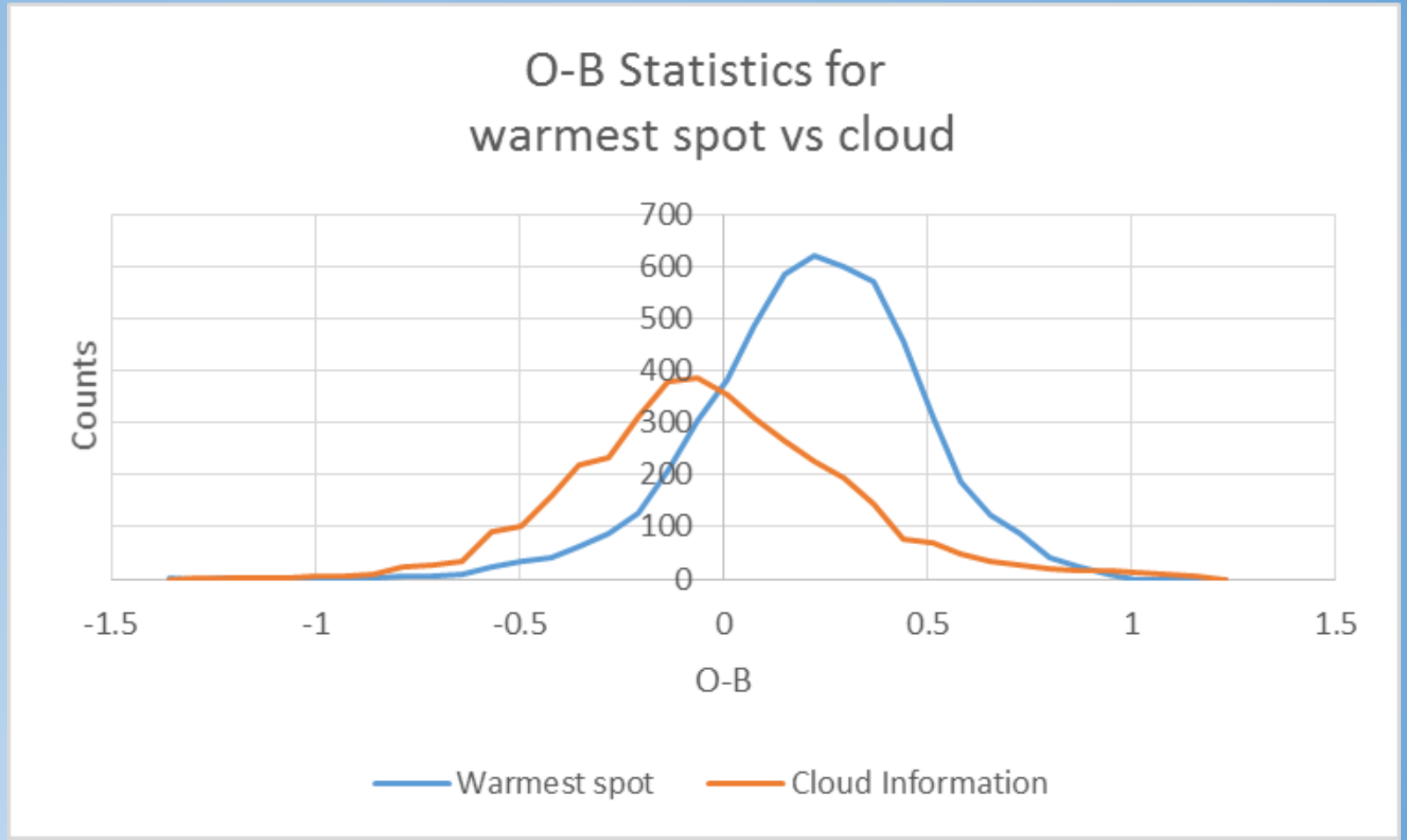




O-B Statistics

Blue – Statistics from warmest spot.
Warm bias, left skewed, cold tail (typical)

GOLD – Independent cloud information used.
Broader distribution, bias consistent with this channel, typically more symmetric.



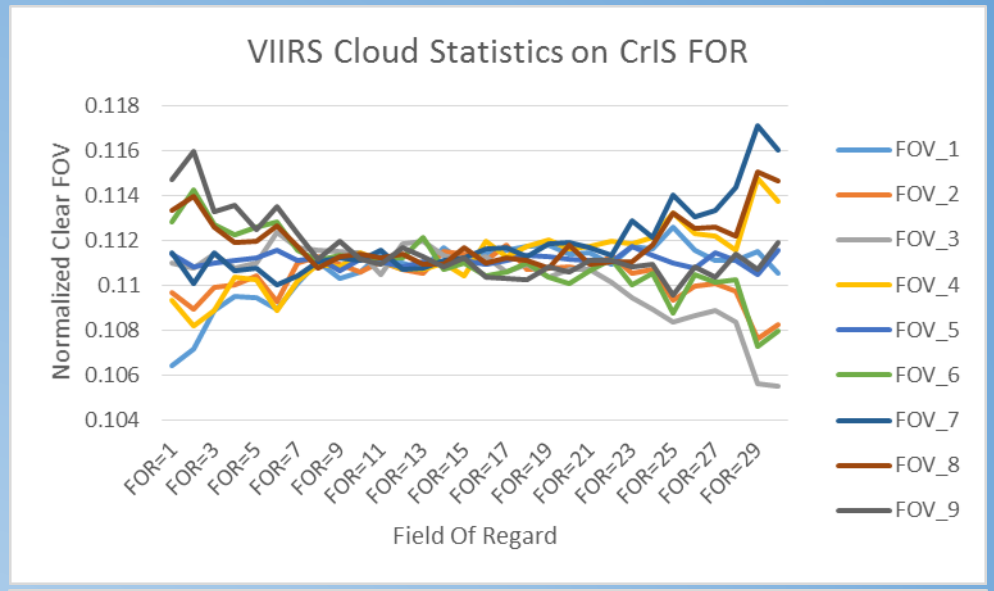
Clear FOV Statistics

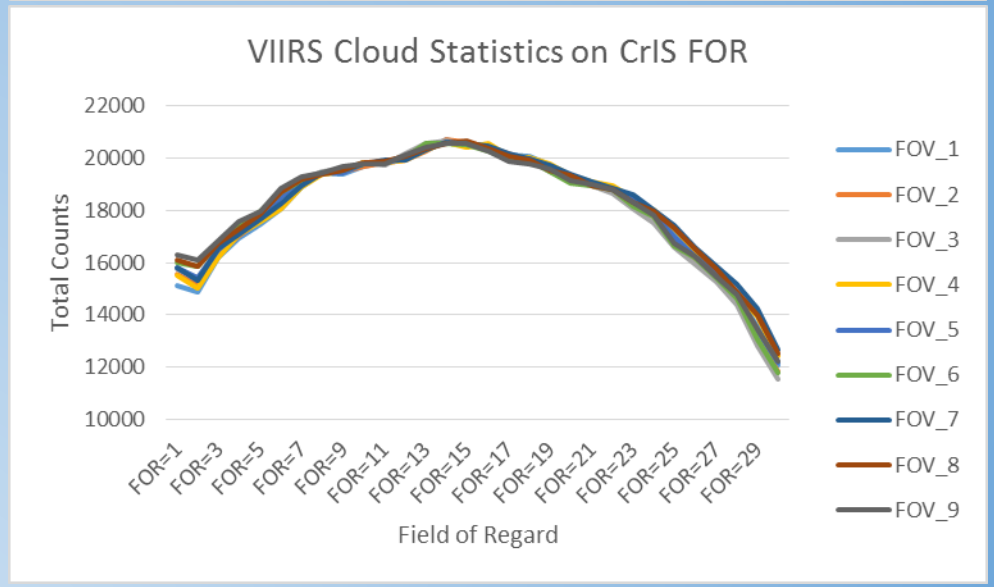
Enterprise VIIRS cloud algorithm mapped onto the CrIS field-of-view.

Clear fields-of-view within each field-of-regard should be about equal (~11%).

Number of clear fields-of-view are expected to have a maximum at nadir and decrease toward the limbs.

Chart should be symmetric around nadir?





Questions?

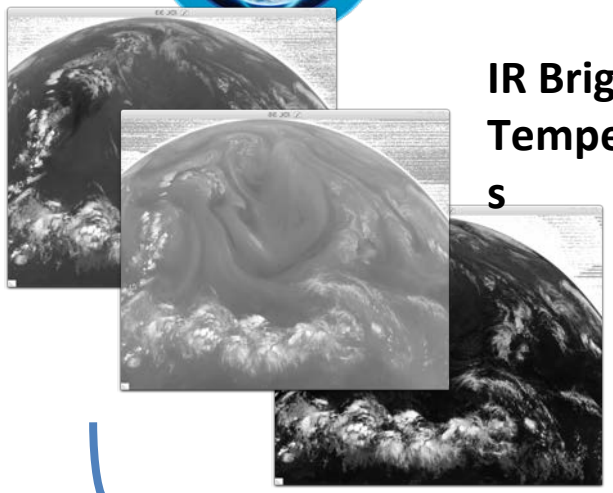
Jim.Jung@noaa.gov



Enterprise Cloud Height Status, Progress and Applications

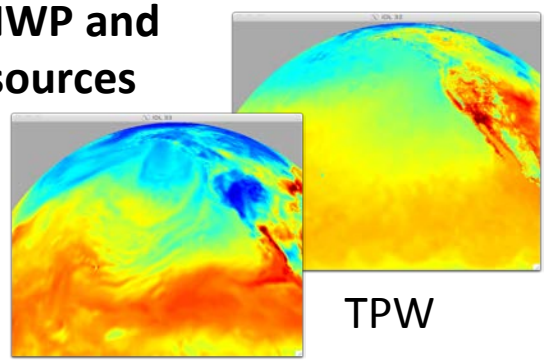
Andrew Heidinger
Yue Li, Steve Wanzong
JPSS Cloud Team

How AWG CLOUD HEIGHT (ACHA) Works



IR Brightness Temperatures

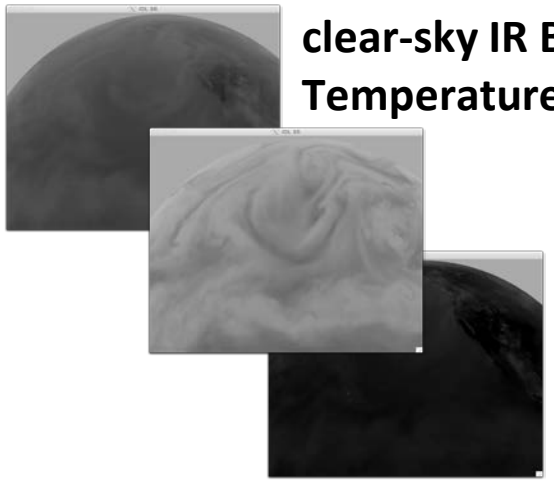
Ancillary Data from NWP and other sources



surface temperature

TPW

Radiative Transfer Model clear-sky IR Brightness Temperatures

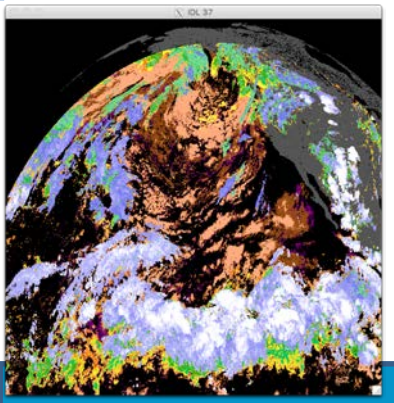


ACHA Input

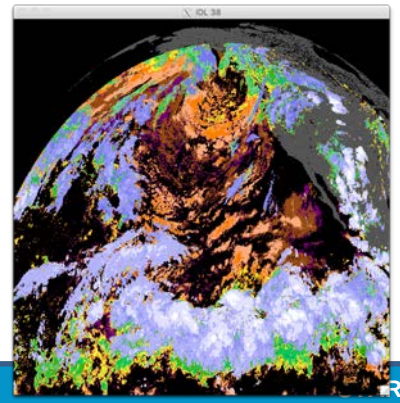
Optimal Estimation

ACHA Output

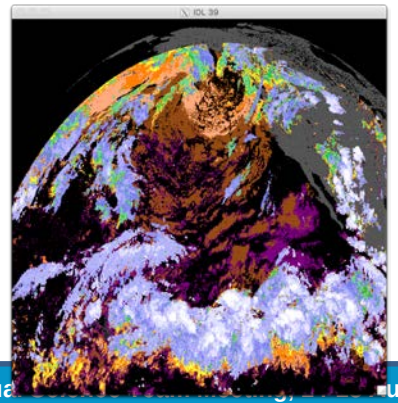
cloud pressure



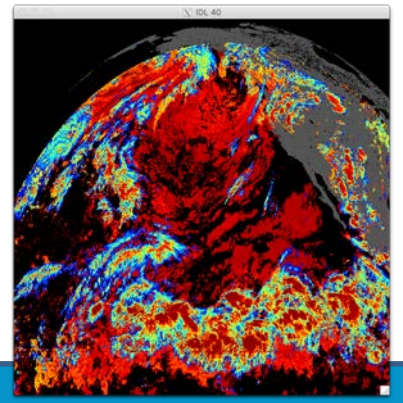
cloud height



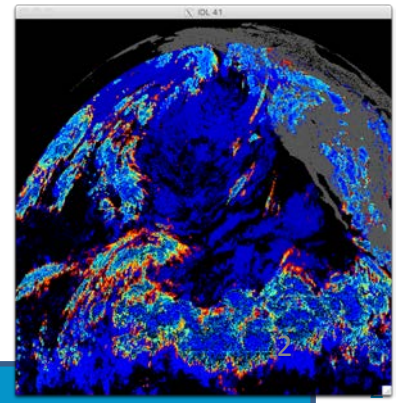
cloud temperature



cloud emissivity



cloud pressure errors



Users of Enterprise Height Products and Software

Software

- Japanese Meteorological Agency (JMA): (ACHA run in their own system).
- Australian Bureau of Meteorology (ABOM): ACHA run for local AMV generation.
- Taiwan Central Weather Bureau: Enterprise algorithms run in CSPP.
- Naval Research Laboratory: ACHA run to support a MURI project.
- CIRA: ACHA part of suite run in CLAVR-x to support solar energy forecasts.
- CSPP: Both LEO and GEO versions.
- NASA NPP MODIS Continuity Project uses ACHA in CLAVR-x in its processing chain.

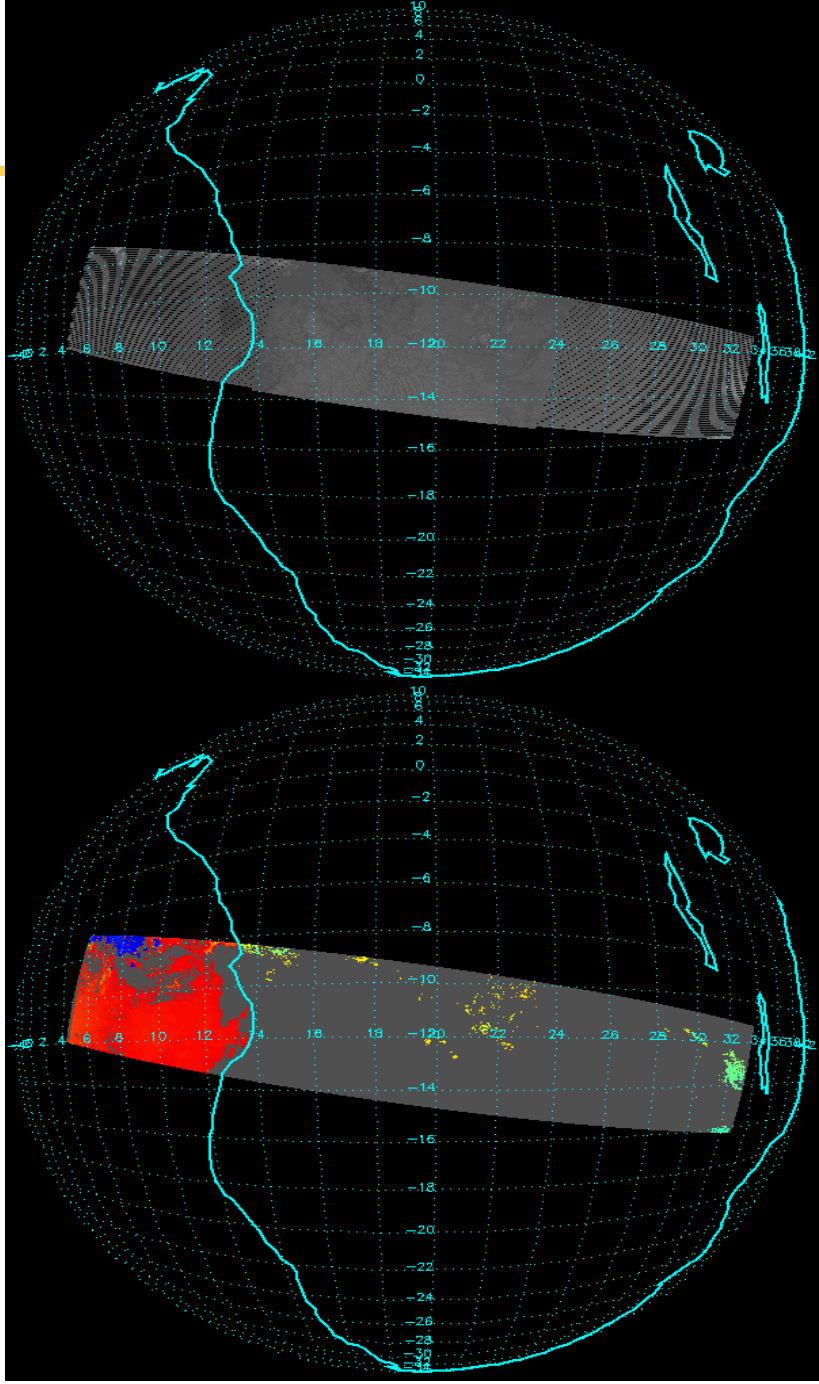
Products

- NWS Aviation Weather Center: ACHA, BASE and CCL from global geos and polar VIIRS.
- Boeing: ACHA from all GEO sensors.
- NESDIS Operations AMVs (GEO and VIIRS).
- NCEP All-sky radiance assimilation stratification (clear and by cloud layers).
- NCEP RTMA (tbd).

OSPO/NDE Operational Status

Enterprise Cloud Algorithms Operational Status

- The NOAA Enterprise Cloud Products (Mask, Phase, Height, Day/Night Optical) became operational on July 7, 2017 and available on PDA.
- Data should be available to public via CLASS on August 23.
- Operational version (v1r1) was that from June 2016.
- Updates delivered January 2017 and August 2017 are not yet running in NDE.

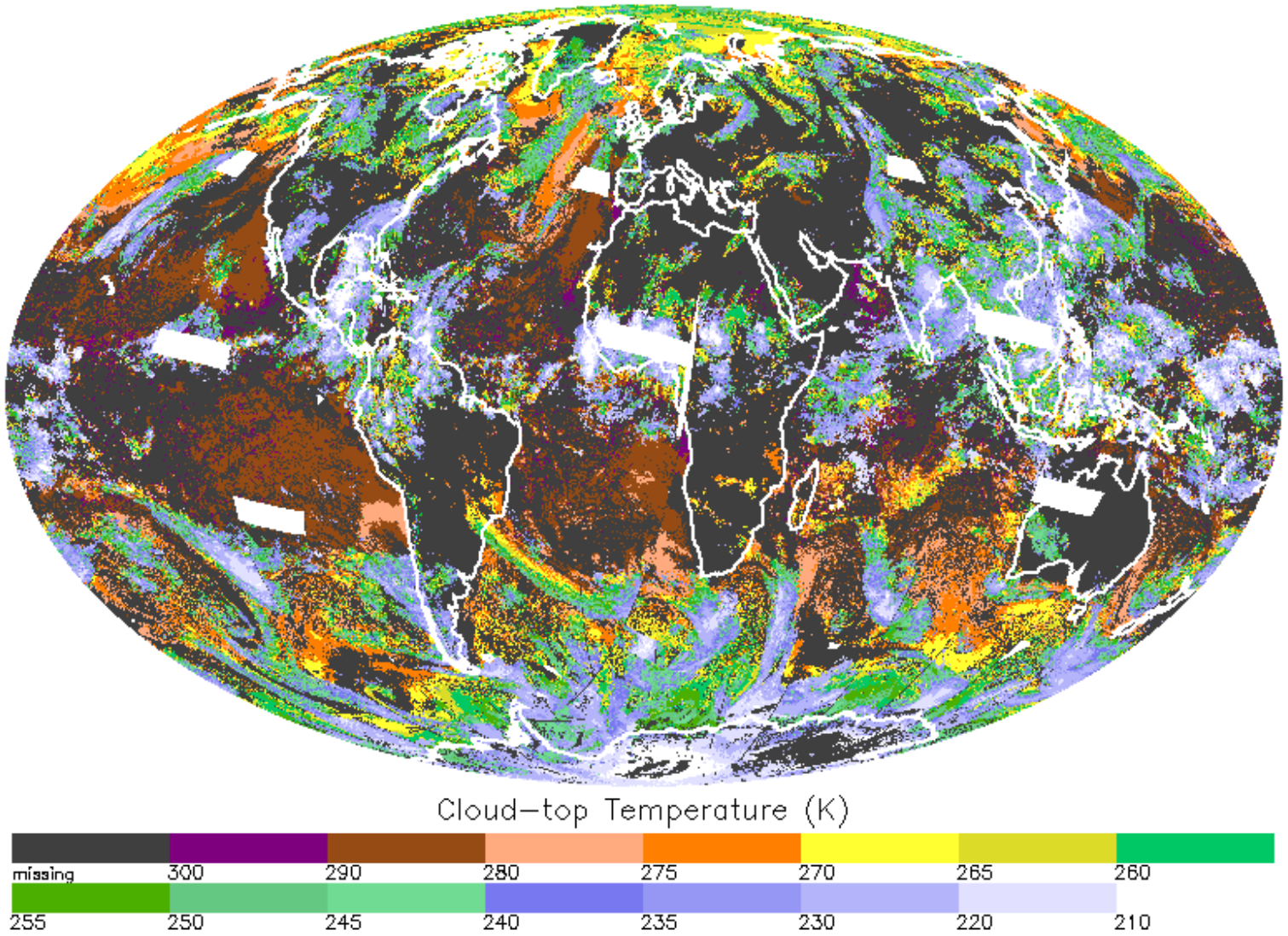


Images show about 8 hours of NDE Enterprise Output. Top image is the 11 micron BT and the bottom image is the NDE operational cloud-top pressure product.

Global Views of NDE Output

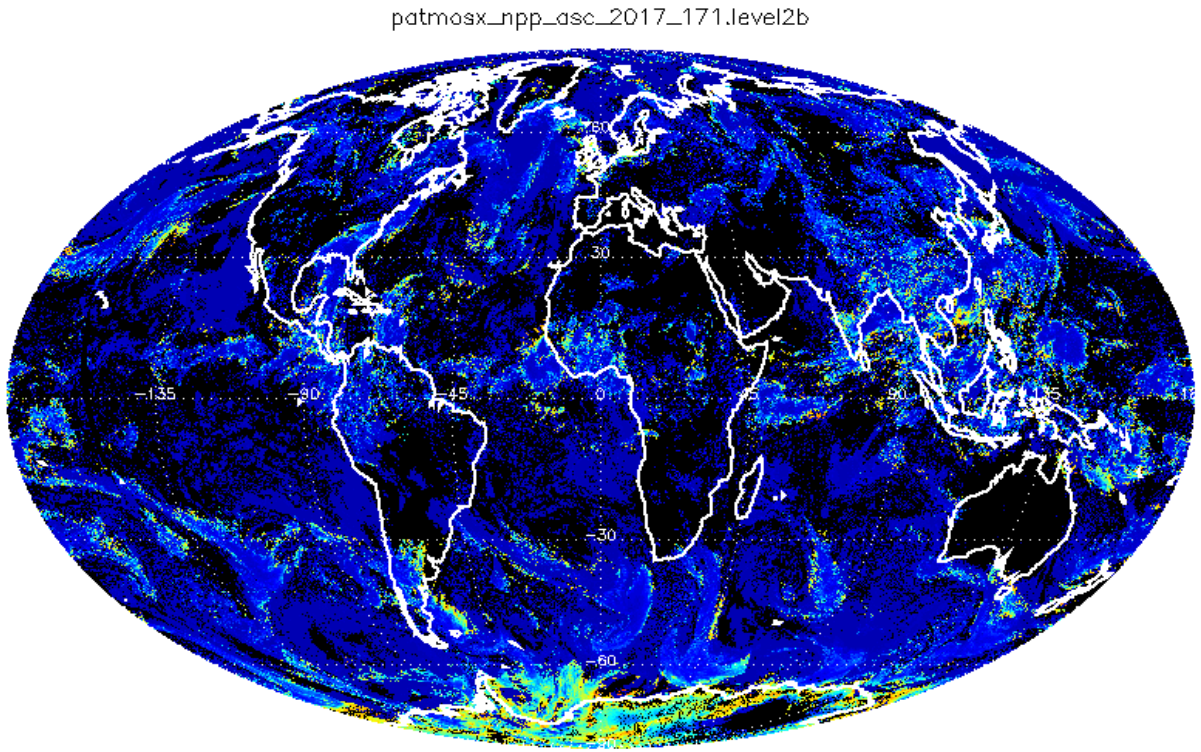
Issues:

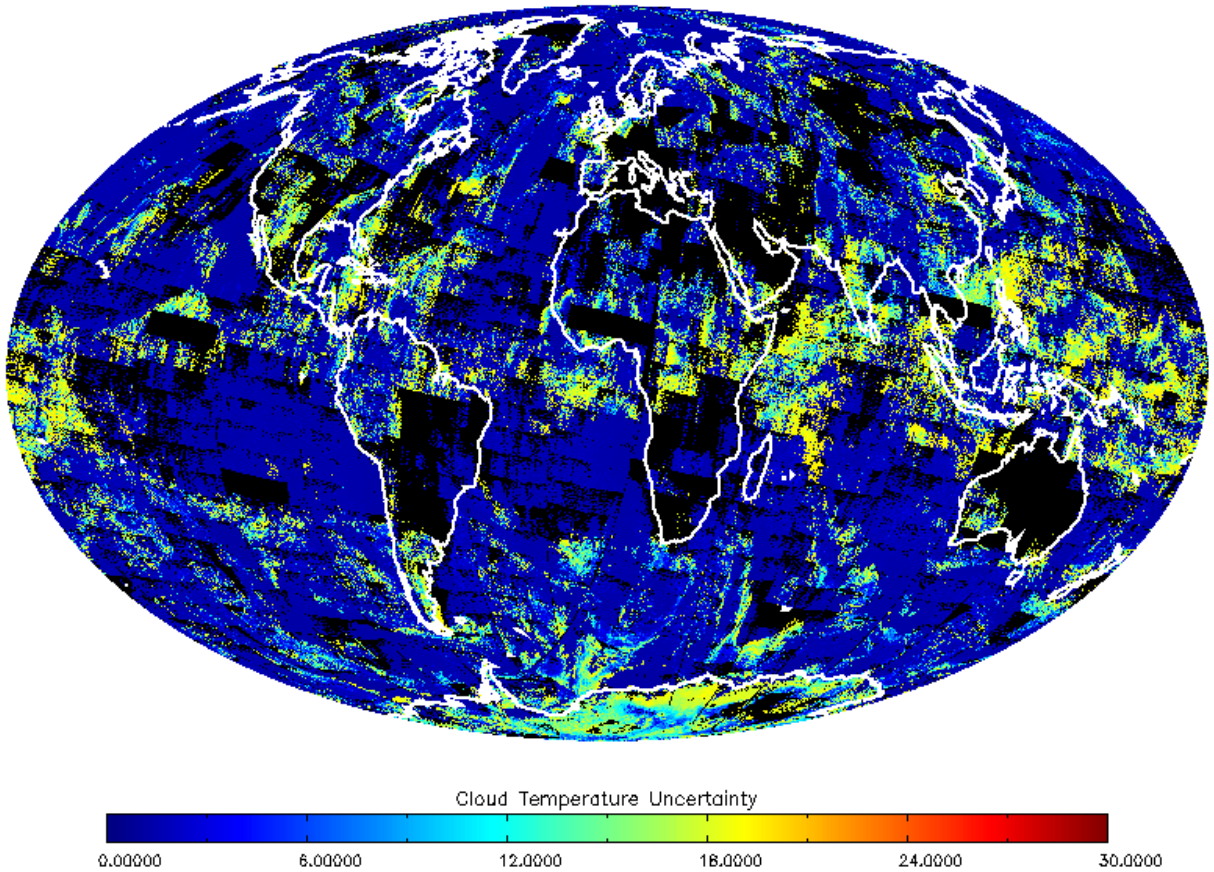
- A few missing granules per day on all days tested.
- Edge of granules are missing. VIIRS maximum zenith angle is larger than maximum supported by CRTM/SAPF



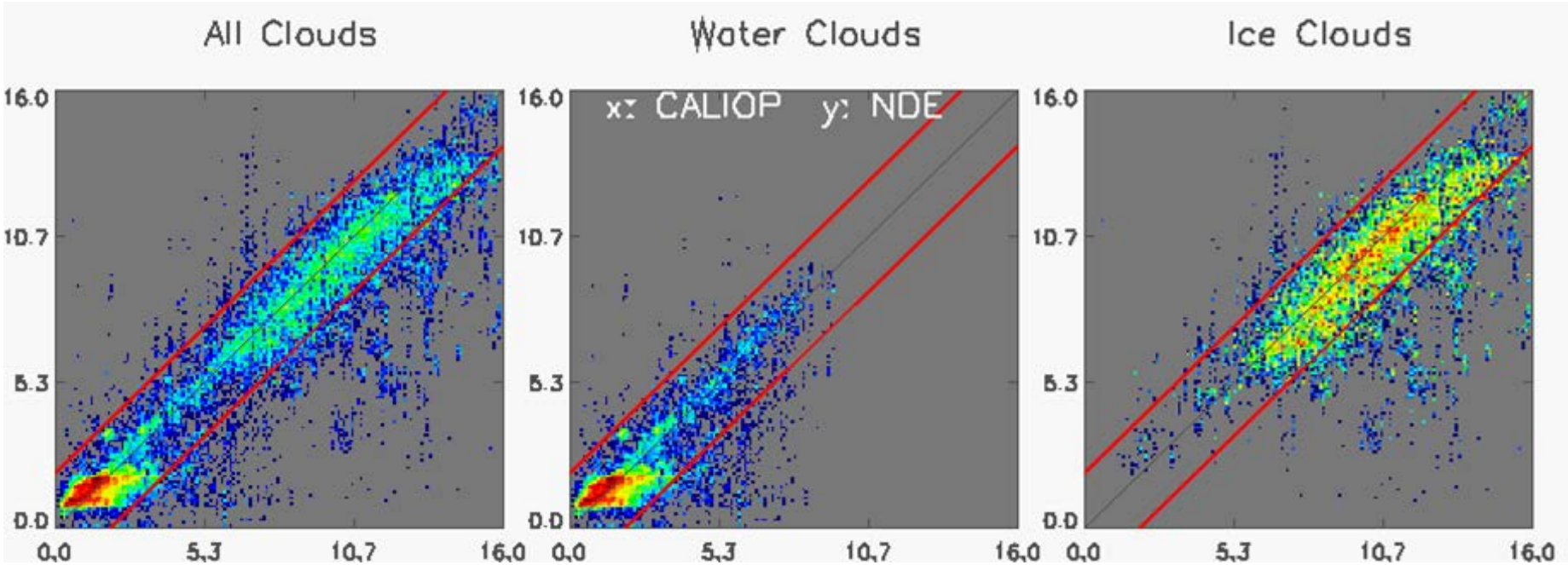
Issues Contd.

Cloud Top Temperature Uncertainty is not correctly written to file.





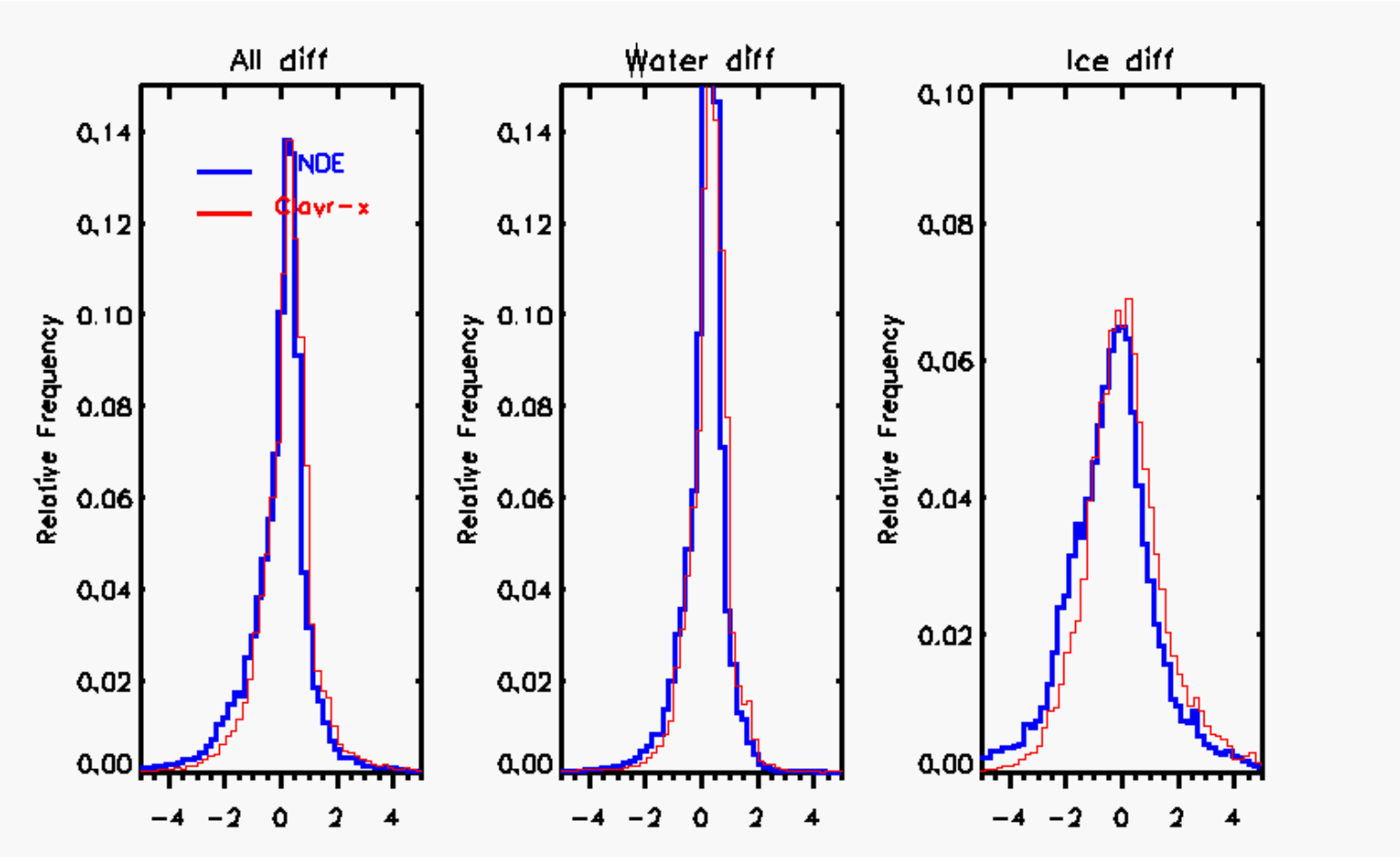
NDE vs Calipso



60◦N-60◦S, Phase matching, single layer						
Type	Bias (km)	StdDev(km)	Corr	Counts	Within Specs-Accuracy	Within Specs-Precision
All clouds	-0.3	1.26	0.96	69060	81.9%	82.3%
Water	-0.02	0.80	0.83	46050	90.7%	90.8%
Ice	-0.87	1.74	0.75	23010	64.5%	65.7%

Histogram Distribution of differences between VIIRS and Calipso

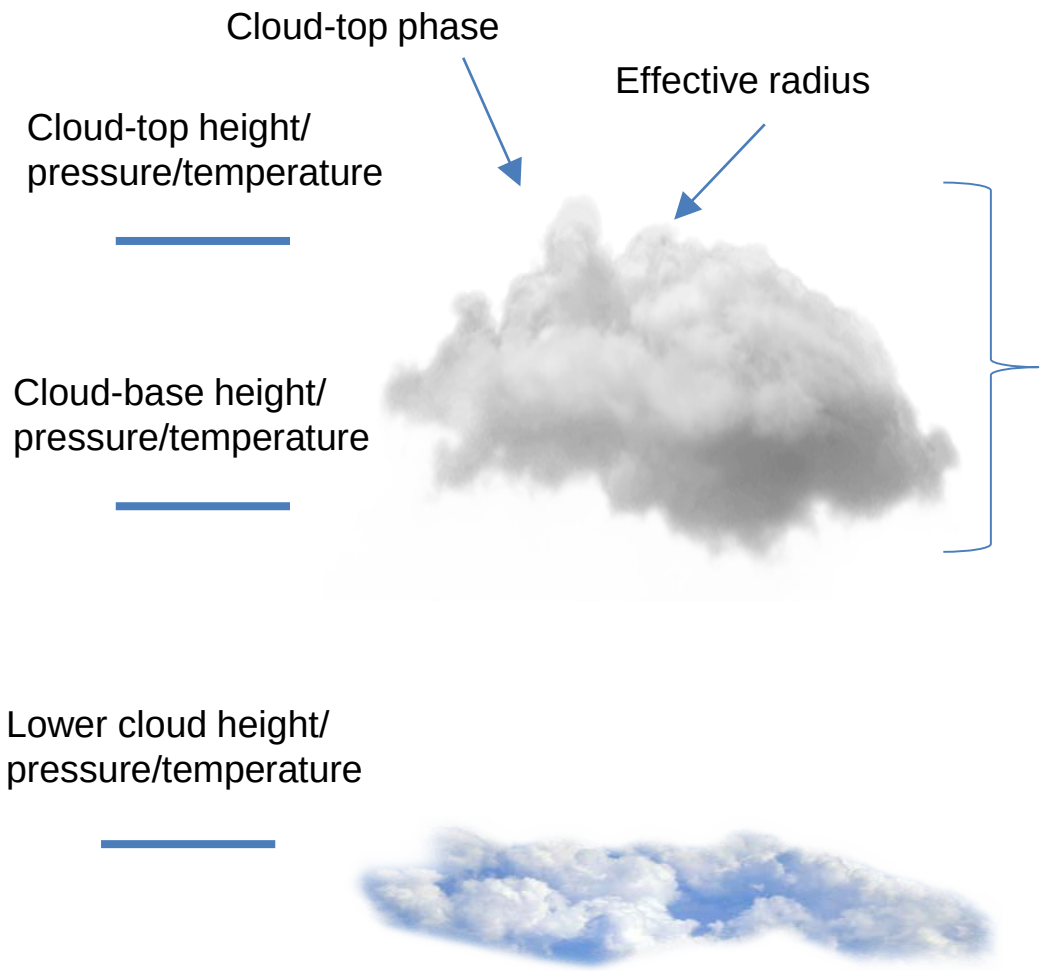
- Phase matching and single layer filtering is applied to 06/20/2017
- Calipso from the same day is collocated and compared
- An independent comparison using current Clavr-x product is provided and shows similar performance
- Current cloud height retrieval indicates a slightly larger estimation, which makes a positive impact compared to NDE (next two slides)



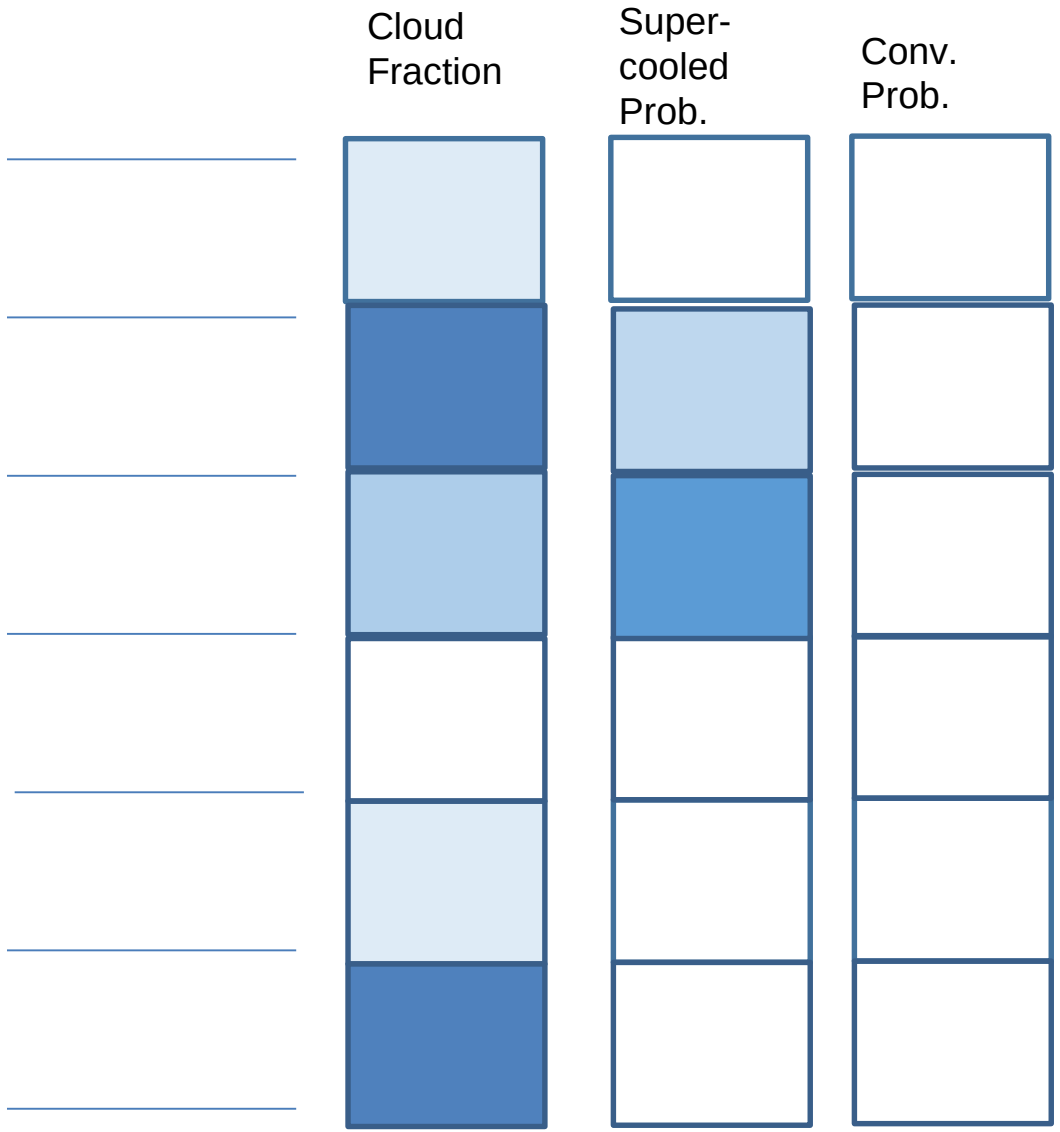
CLOUD COVER LAYERS APPLICATION

Cloud Cover Layers Application

Pixel-level Cloud Products (Mask/Phase/ACHA+Base)

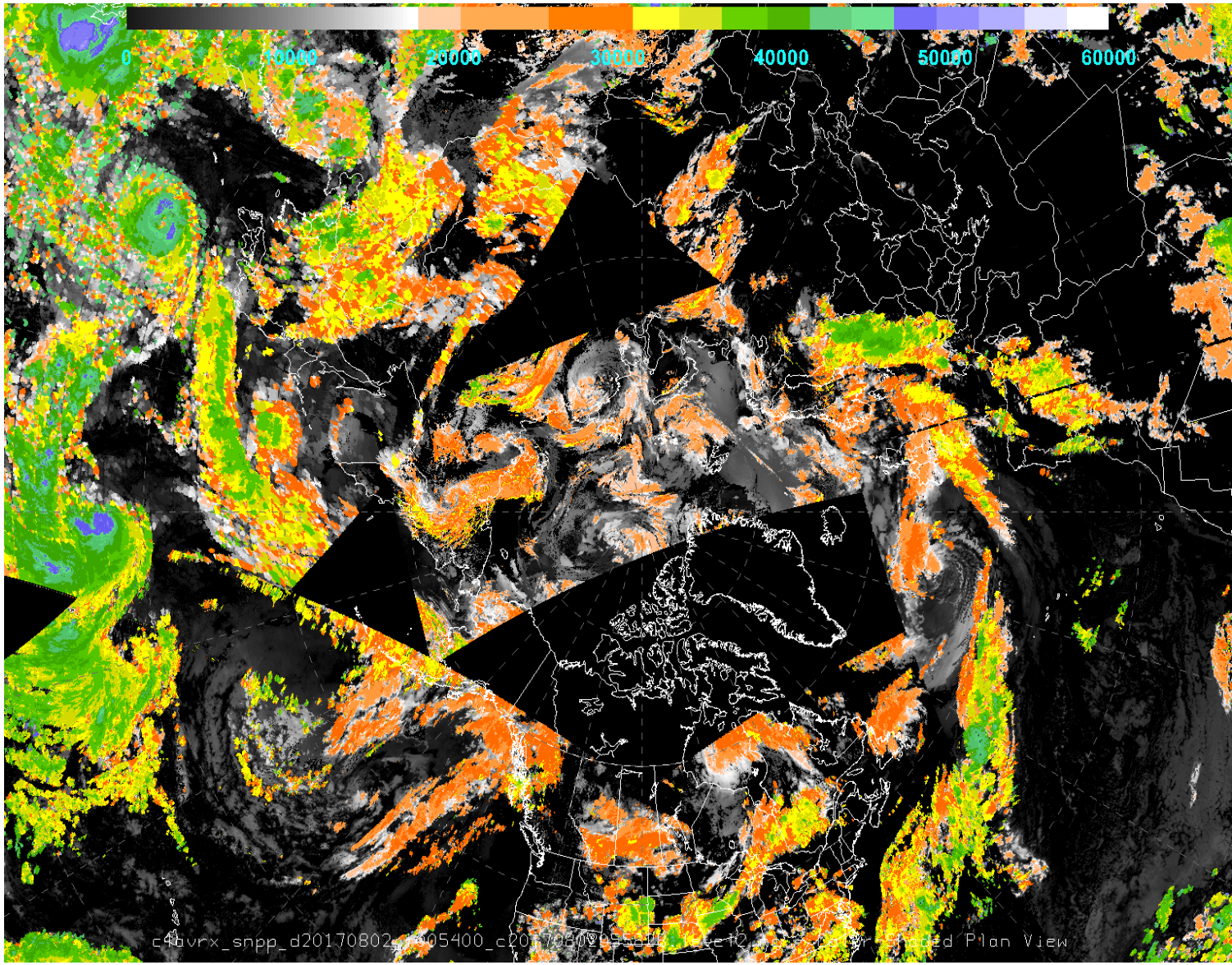


Gridded (10 km) Cloud Cover Layers



Merging VIIRS and GEO for AWC

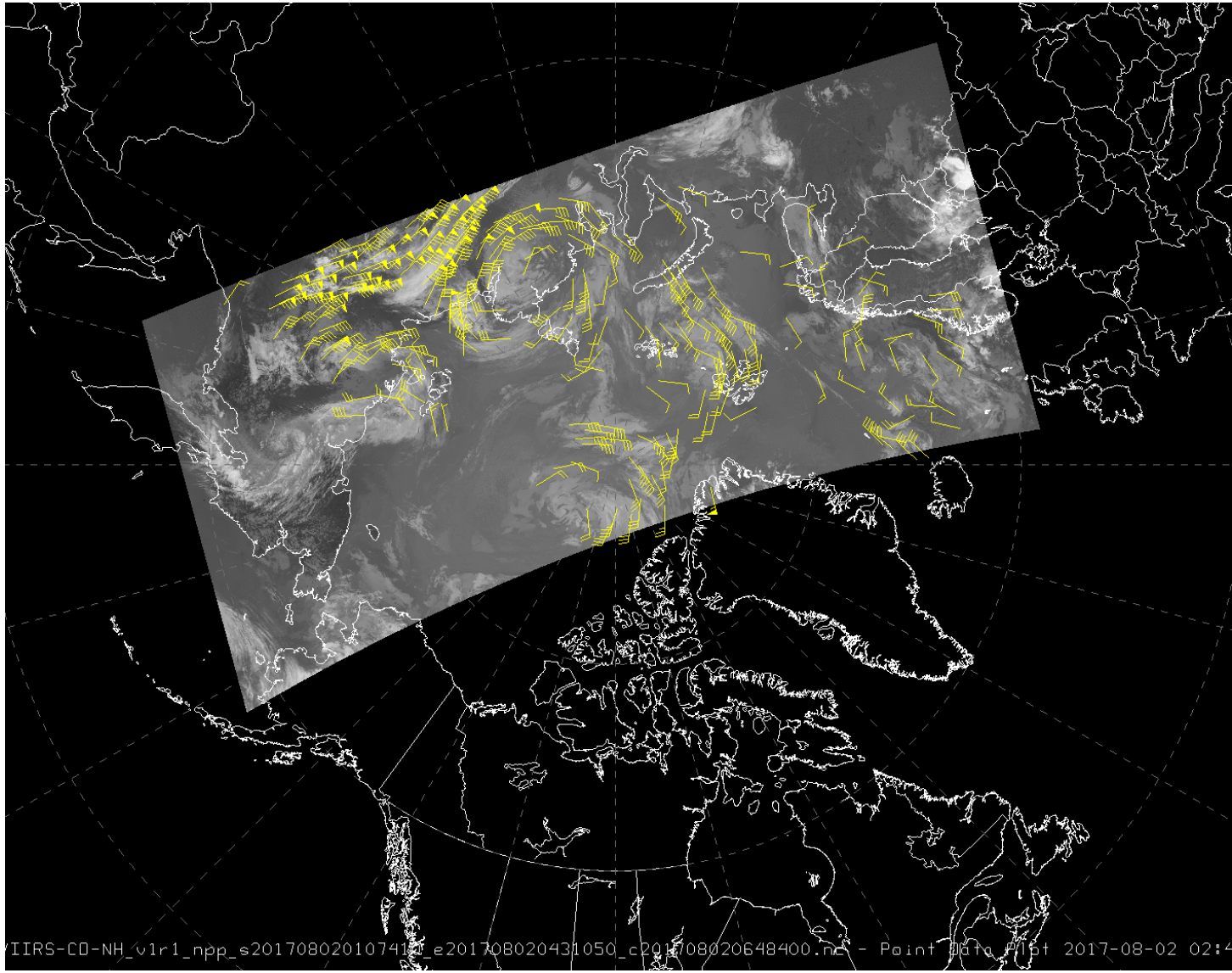
- Image contains one day of cloud-top altitude (ft).
- Arctic data is from SNPP VIIRS
- Non-Arctic data is from the global geostationary constellation.
- Global-geo has been served to NWS AWC since 2014.
- We plan to add VIIRS now that products are operational (see image on right)
- Data will be served to AWC via CIMSS.
- PSDI support will be sought to move all of this in NESDIS ops.
- Products will include the CCL supported under JPSS-RR.



AMV APPLICATION

VIIRS Arctic AMVs for day 2017, August 02

- Initial NWP impact shows mostly neutral to slightly positive NWP impact. Reported by Iliana Genkova at IWW13 in June 2016.
  - –Planned for operational use in the GSI Quarter 3 Fiscal Year 2017.
- All supported sensors use the same AMV software in the Enterprise framework.
  - –Includes both leo and geo sensors.



Enterprise VIIRS AMV RAOB statistics - Arctic

100 - 1000 hPa	All Levels
Accuracy	5.89
Precision	3.48
Speed Bias	0.52
Average Speed	21.79
Sample Size	12784

- Data is from 1 February - 30 June, 2017.
- GOES-R Metrics: 7.5 ms-1 Accuracy; 4.2 ms-1 Precision.
- QI > 80

Enterprise VIIRS AMV RAOB statistics - Antarctic

100 - 1000 hPa	All Levels
Accuracy	6.10
Precision	4.16
Speed Bias	-0.25
Average Speed	15.72
Sample Size	1339

- Data is from 1 February - 30 June, 2017.
- GOES-R Metrics: 7.5 ms-1 Accuracy; 4.2 ms-1 Precision.
- QI > 80

ACHA Algorithm Changes since 2016

Multi-layer Solution

- ACHA always accounted for multi-layer clouds when detected, now temperature of lower layer has been added to the O.E. state vector.
- Very promising performance but varies with spectral content.

Microphysical Models

- Made this a compile-time option and expanded the number of options.
- Analysis has shown this does impact cloud heights appreciably.

Sounder/Imager Fusion

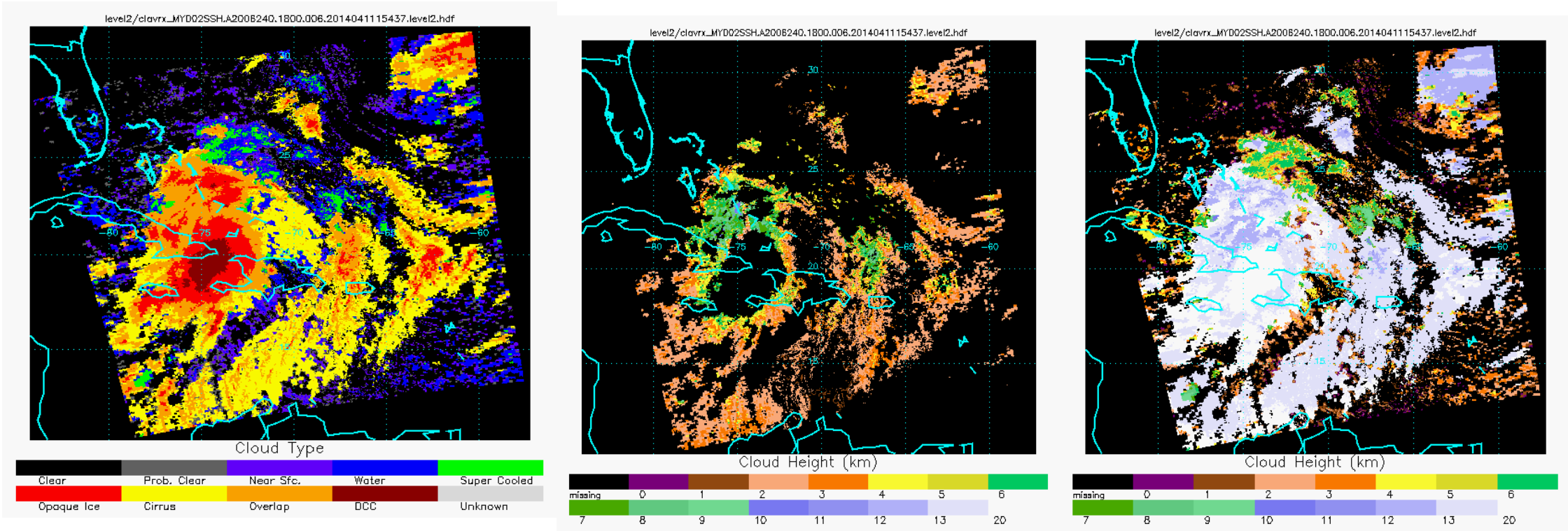
- Finalized use of CrIS data to make CO_2 slicing heights which are used in ACHA O.E.
- Paper drafted and results shown here.
- Studying use of NUCAPS heights and transitioning to operations.

Spectral Channels

- ACHA has always supported many 1,2 or 3 channel combinations. Now we support some 4 and 5 channel combinations. Default for VIIRS remains 8.5, 11 and 12 microns.
- Paper drafted on optimal channel combinations revealed by CALIPSO/CALIOP.

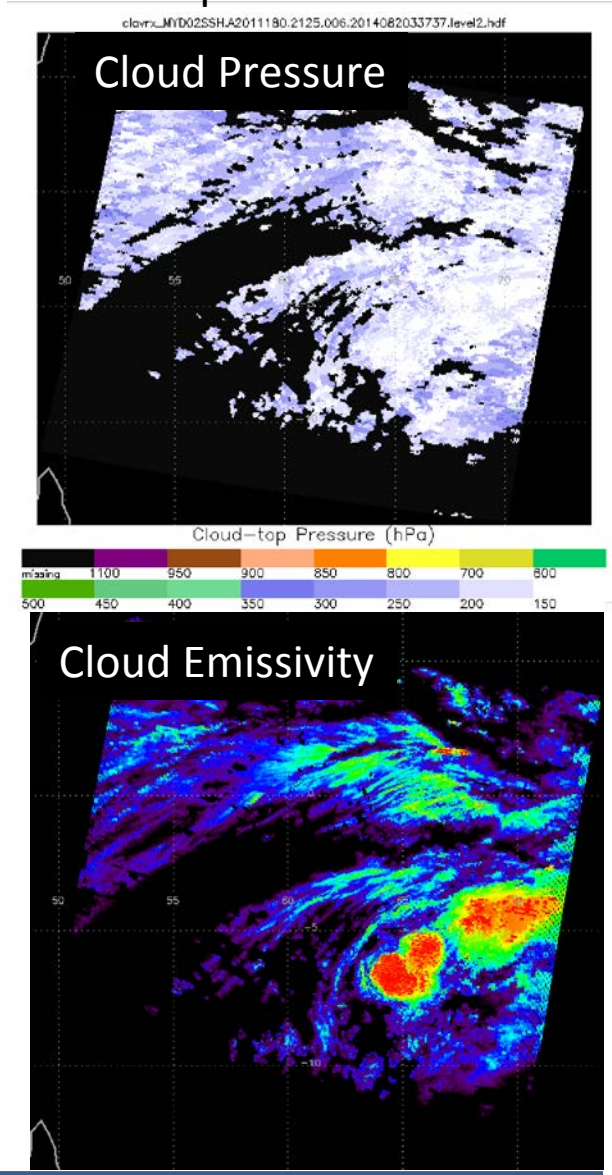
Multi-Layer Cloud Height

- AWG Cloud Height can now directly retrieve height of lower cloud layers.
- It can also determine its own multilayer scenes. (experimental)
- Limited to high thin over low cloud.
- Important for the CCL application and low level AMV targets.

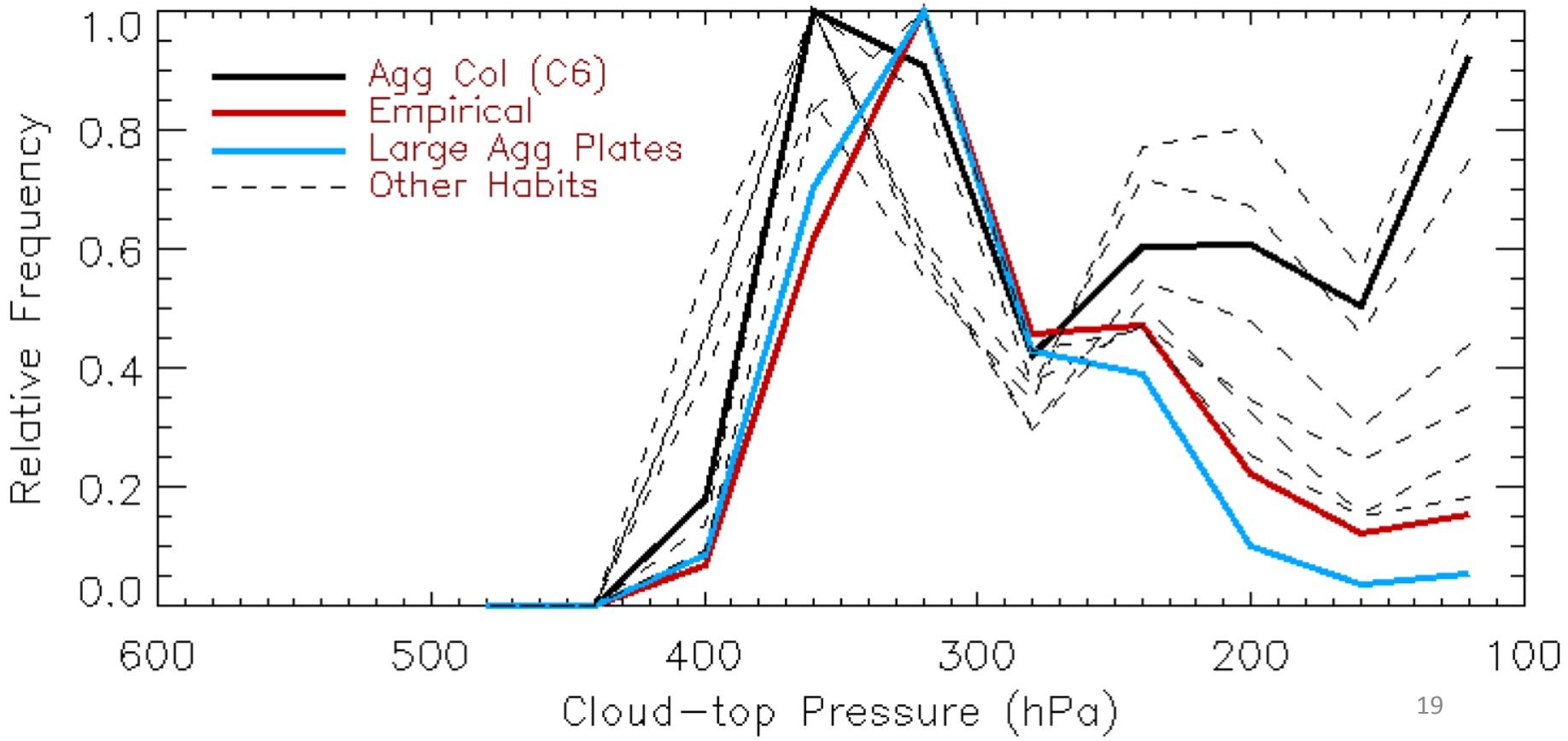


Impact of Ice Crystal Habit Choice on Cloud Height

Example VIIRS Scene

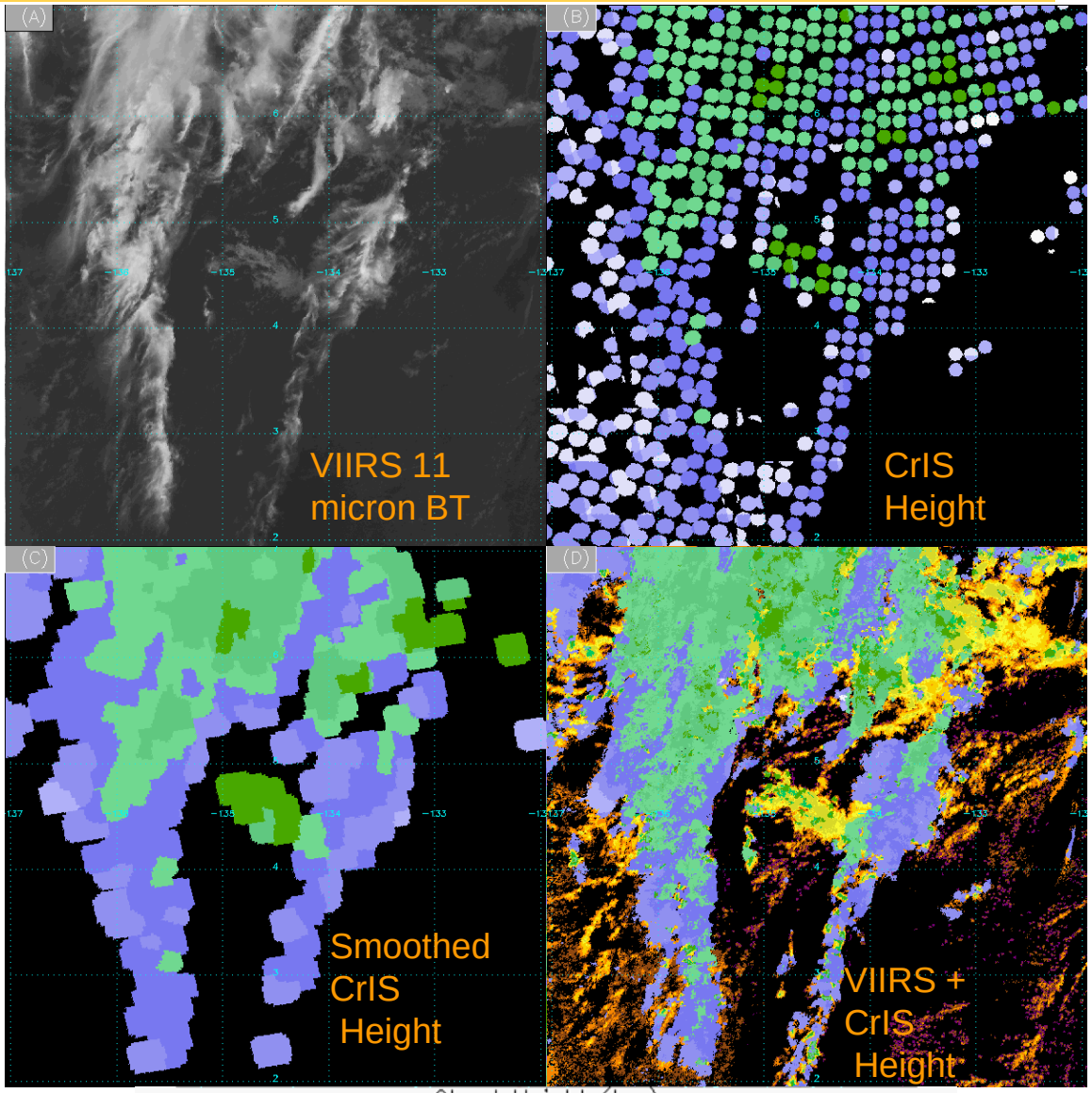


- MODAWG uses the Aggregate Column Habit as did MODIS C6
- This was chosen to improve VIS and IR consistency in optical depth
- The images below show the cloud-top pressures predicted **solely based on a direct inversion using the 8.5, 11, 12 µm channels and each habit.**
- Unfortunately, Agg Col solutions often go very high and are not optimal.
- The Empirical model is based on spectral consistency between 8.5-11-12 µm



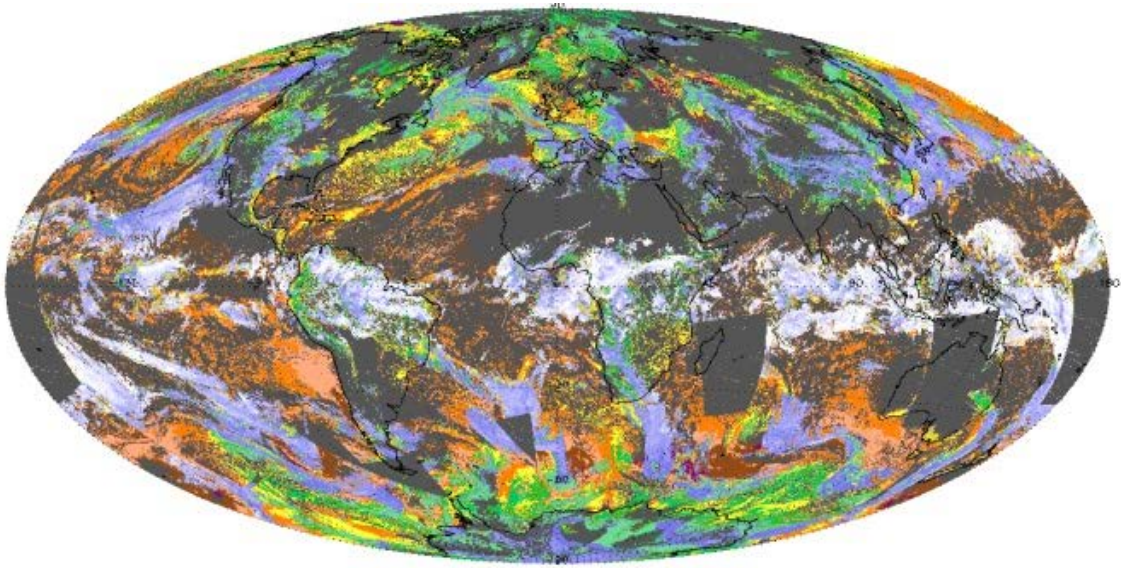
Imager/Sounder Merge

- VIIRS lacks IR bands in CO_2 or H_2O absorption bands that are present on GOES-16 and MODIS.
- Leveraging from the ***NASA SNPP MODIS Continuity Project***, we developed a methodology to merge with CriS to improve performance.
- Currently, we make MODIS CO_2 bands from CrIS and run a MODIS-ish CO_2 slicing. (top right)
- These sounder heights for ice clouds are spatially smoothed (lower left)
- The smoothed sounder heights are added as a new constraint to the ACHA IR Optimal Estimation.
- Benefits
  - ***Utilizes sounder spectral information***
  - ***Preserves imager spatial resolution***
- Applications
  - Polar Winds (need high spatial for tracking)
  - Radiance Assim - better cloud stratification
  - Climate - better cloud depiction - consistency with MODIS/GOES-16
- Future
  - Submit publication
  - Explore using NUCAPS as the sounder height source.
  - Look again at VIIRS pixel level CrIS Bands (Fusion)



Conclusions

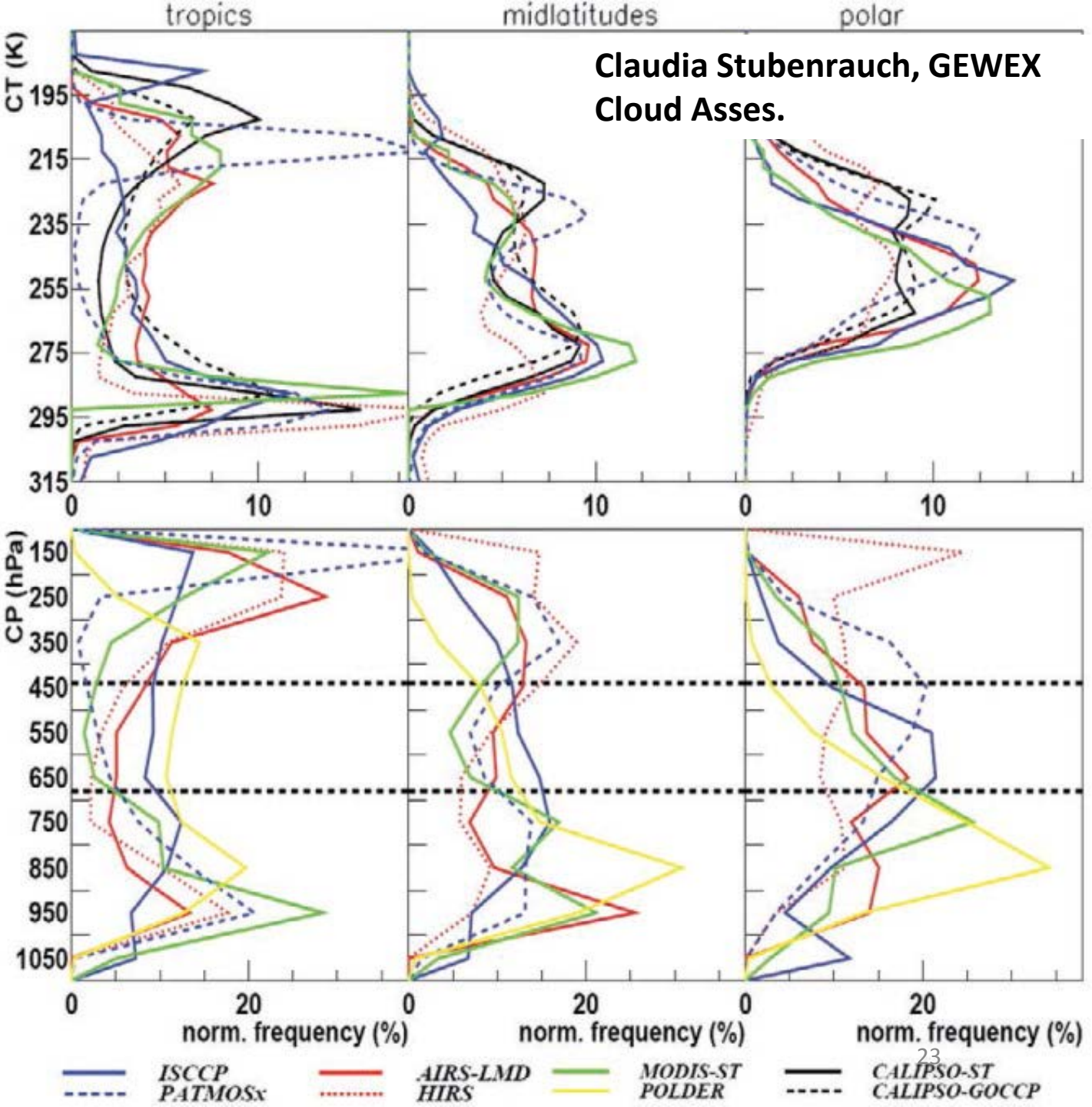
- ACHA is operational now in NDE.
- Performance seems as expected with a few lingering issues.
- We hope CCL from VIIRS can join global-geo CCL for AWC.
- ACHA's use in AMV application appears to be successful.
- We hope the use of ACHA for VIIRS/CrIS All-sky Radiance Assimilation is also successful.
- Several algorithm developments are ongoing and hold promise for improved performance.



The End, Thank You!

Challenge of Cloud Height Consistency

- Image shows cloud top temperature (top) and cloud pressure (bottom) from GEWEX Cloud Assessment.
- **Variation among sensors and groups is large.**
- Sensors with IR abs channels can use slicing or sorting techniques.
- Sensors with only IR window channels rely on microphysical techniques which are more problematic.



Additional AMV Stats

Enterprise VIIRS AMV RAOB statistics - Arctic

101 - 400 hPa	Upper Levels
Accuracy	6.38
Precision	3.58
Speed Bias	0.51
Average Speed	26.94
Sample Size	5528

- Data is from 1 February - 30 June, 2017.
- GOES-R Metrics: 7.5 ms-1 Accuracy; 4.2 ms-1 Precision.
- QI > 80

Enterprise VIIRS AMV RAOB statistics - Arctic

401 - 700 hPa	Middle Levels
Accuracy	5.72
Precision	3.30
Speed Bias	0.59
Average Speed	20.03
Sample Size	5525

- Data is from 1 February - 30 June, 2017.
- GOES-R Metrics: 7.5 ms-1 Accuracy; 4.2 ms-1 Precision.
- QI > 80

Enterprise VIIRS AMV RAOB statistics - Arctic

701 - 1000 hPa	Lower Levels
Accuracy	4.87
Precision	3.40
Speed Bias	0.28
Average Speed	10.97
Sample Size	1731

- Data is from 1 February - 30 June, 2017.
- GOES-R Metrics: 7.5 ms-1 Accuracy; 4.2 ms-1 Precision.
- QI > 80

Enterprise VIIRS AMV RAOB statistics - Antarctic

101 - 400 hPa	Upper Levels
Accuracy	6.55
Precision	3.61
Speed Bias	-0.70
Average Speed	19.13
Sample Size	597

- Data is from 1 February - 30 June, 2017.
- GOES-R Metrics: 7.5 ms-1 Accuracy; 4.2 ms-1 Precision.
- QI > 80

Enterprise VIIRS AMV RAOB statistics - Antarctic

401 - 700 hPa	Middle Levels
Accuracy	5.76
Precision	4.64
Speed Bias	-0.09
Average Speed	13.39
Sample Size	656

- Data is from 1 February - 30 June, 2017.
- GOES-R Metrics: 7.5 ms-1 Accuracy; 4.2 ms-1 Precision.
- QI > 80

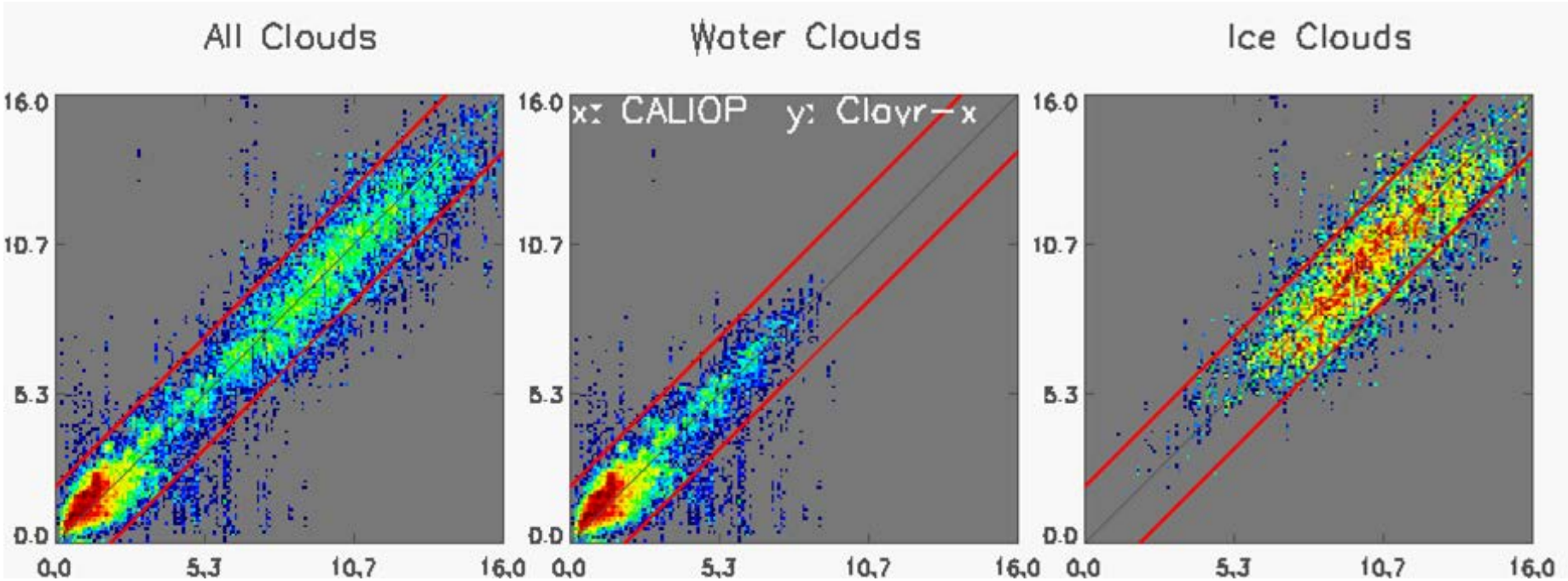
Enterprise VIIRS AMV RAOB statistics - Antarctic

701 - 1000 hPa	Lower Levels
Accuracy	5.58
Precision	3.46
Speed Bias	1.60
Average Speed	9.82
Sample Size	86

- Data is from 1 February - 30 June, 2017.
- GOES-R Metrics: 7.5 ms-1 Accuracy; 4.2 ms-1 Precision.
- QI > 80

Additional CALIPSO Stats

CLAVR-x vs Calipso



60◦N-60◦S, Phase matching, single layer						
Type	Bias (km)	StdDev(km)	Corr	Counts	Within Specs-Accuracy	Within Specs-Precision
All clouds	0.07	0.96	0.97	71997	85.0%	85.2%
Water	0.18	0.77	0.85	51539	91.0%	91.0%
Ice	-0.2	1.3	0.85	20458	70.0%	70.3%

NDE vs Calipso, No phase matching

Type	Bias (km)	StdDev(km)	Corr	Within Specs-Accuracy	Within Specs-Precision
All	-1.25	2.91	0.77	56.5%	34.4%
Tropics	-1.77	3.48	0.79	55.9%	29.6%
Poles	-0.65	2.48	0.61	54.8%	42.0%
Midlat	-1.09	2.70	0.72	56.5%	37.4%
Single Layer	-0.18	2.22	0.84	75.0%	74.3%
Single Layer - thin	-0.85	2.87	0.66	57.1%	66.0%
Single Layer - thick	0.04	0.94	0.96	82.3%	82.4%
Multi layer	-1.84	2.11	0.71	24.8%	47.8%

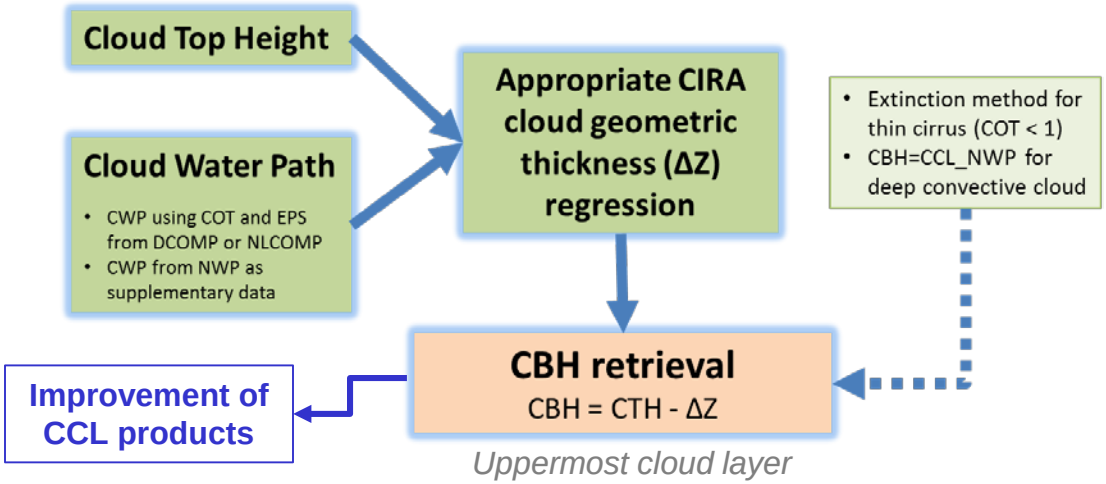
- Correct phase identification is critical for ACHA retrieval
- ACHA performs equally well in different latitude regions, including the Poles
- ACHA performs significantly better under single layer situation than multilayer
- We can now retrieve multilayer cloud height (up to two layers), which is promising to improve general ACHA performance

THE NEWLY OPERATIONAL VIIRS CLOUD COVER/LAYERS AND BASE

Yoo-Jeong Noh
(CIRA/Colorado State University)

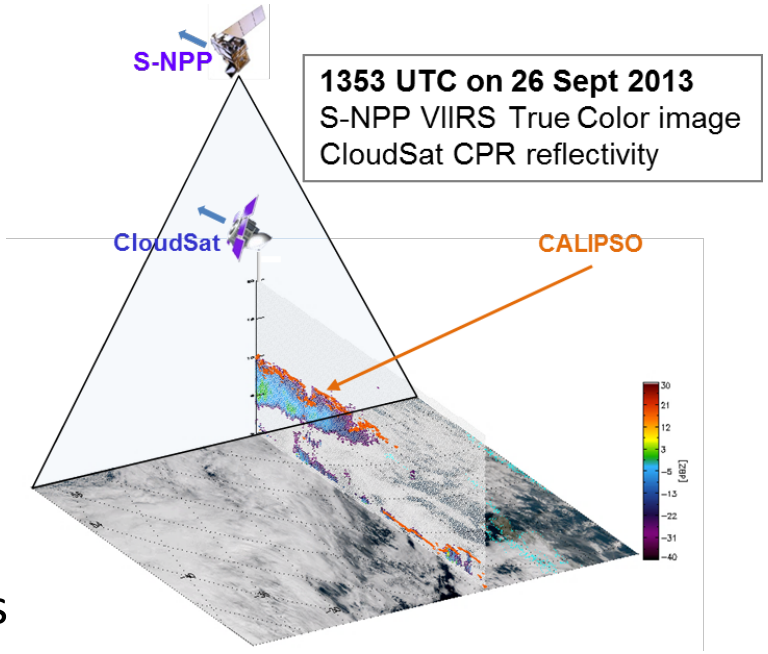
with
Steve Miller, John Forsythe, Curtis Seaman, John Haynes (CIRA)
Andy Heidinger, Dan Lindsey (NOAA/STAR)
Yue Li, Steve Wanzong (CIMSS)

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*)

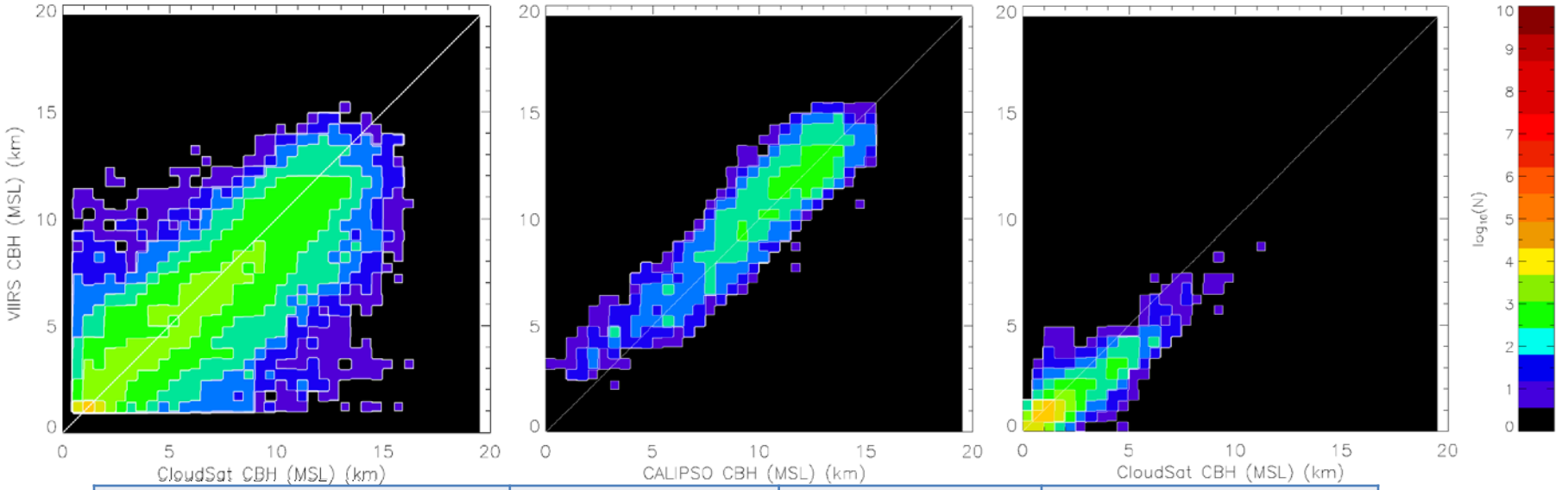
- Knowledge of Cloud Base Height (CBH) is significant to aviation applications and numerical models
- Applied to S-NPP VIIRS and intensively evaluated against CloudSat/CALIPSO (*Seaman et al. 2017*). The new algorithm outperforms the original IDPS CBH algorithm.
- The cloud base information is used for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

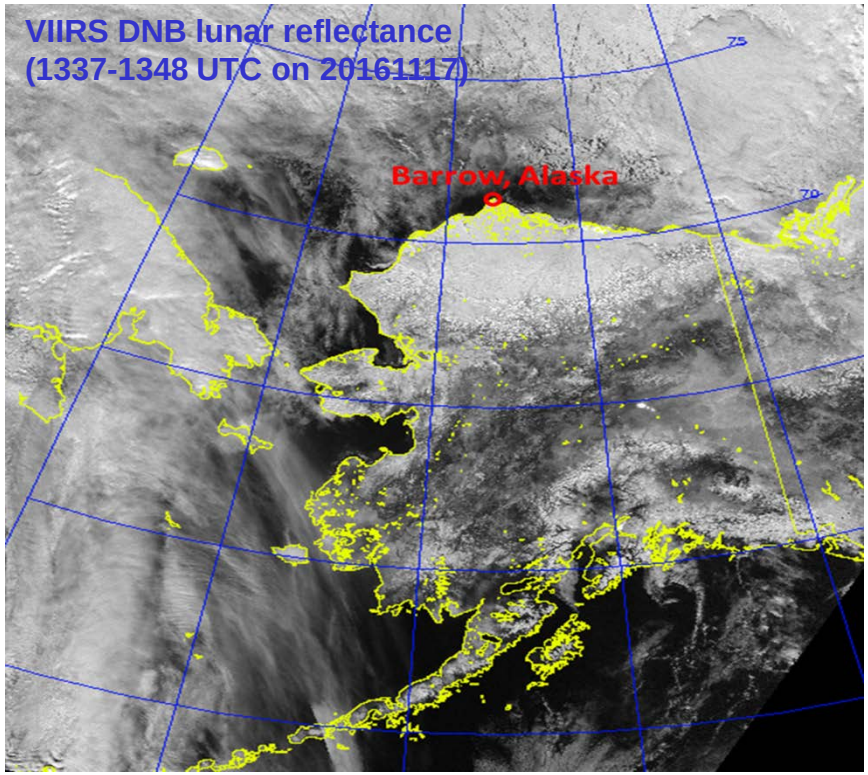
(from 5-month matchup comparisons in 2015 between VIIRS CBH and CloudSat observations)

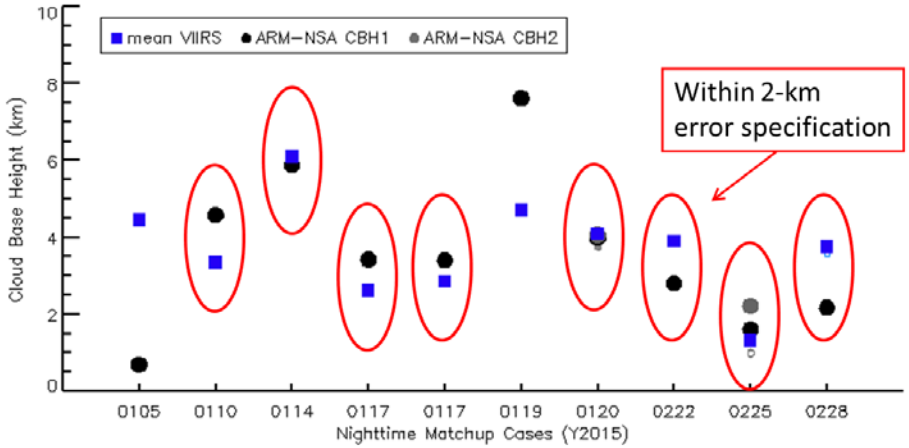
- The Enterprise CBH algorithm code with the ATBD has been delivered to the STAR Algorithm Implementation Team, now running in the operational frame.
- Publications in 2017
  - Seaman et al. 2017: Cloud Base Height Estimation from VIIRS. Part I: Operational algorithm validation against CloudSat. *J. 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

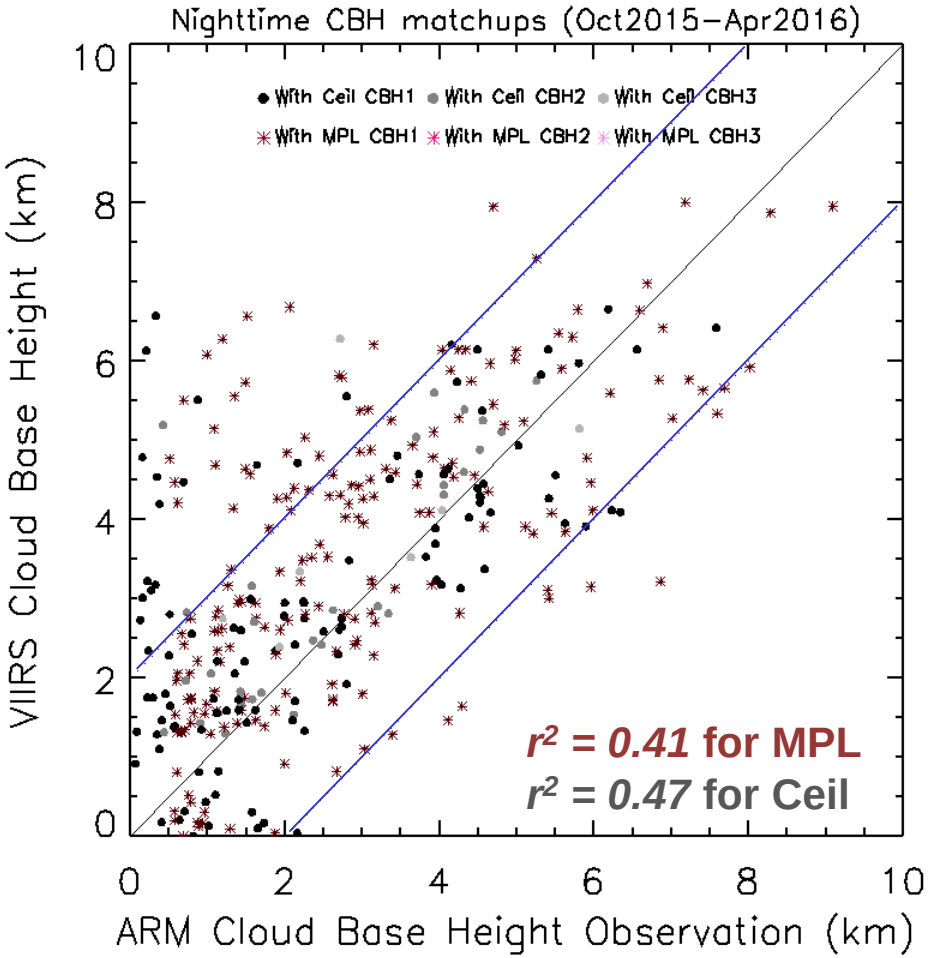
Nighttime CBH algorithm performance





- 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

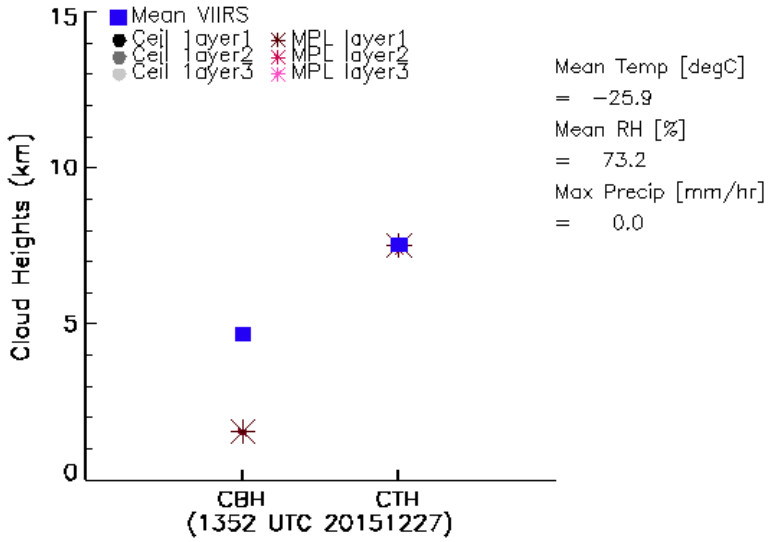
Nighttime CBH algorithm performance

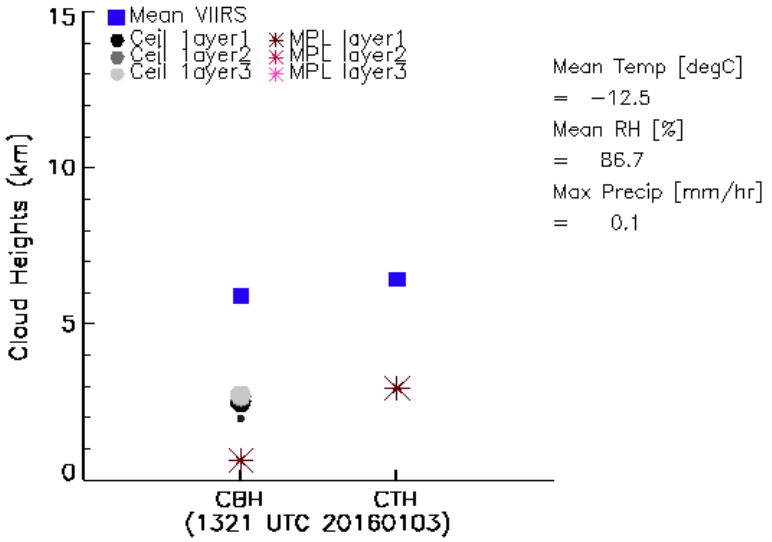


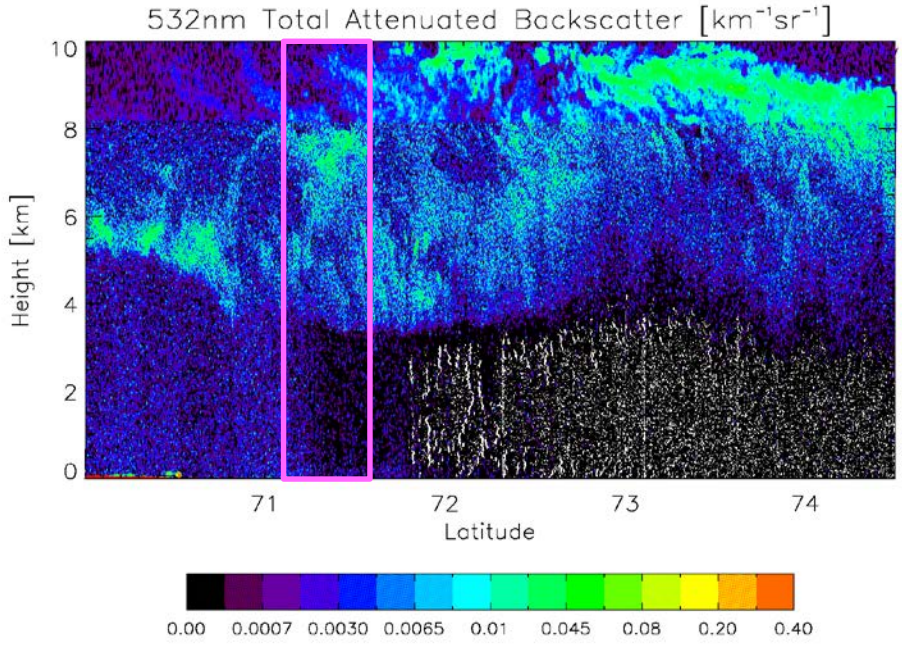
Symbols - CBH1: lowest, CBH3: highest from surface measurements (*precip cases excluded*)

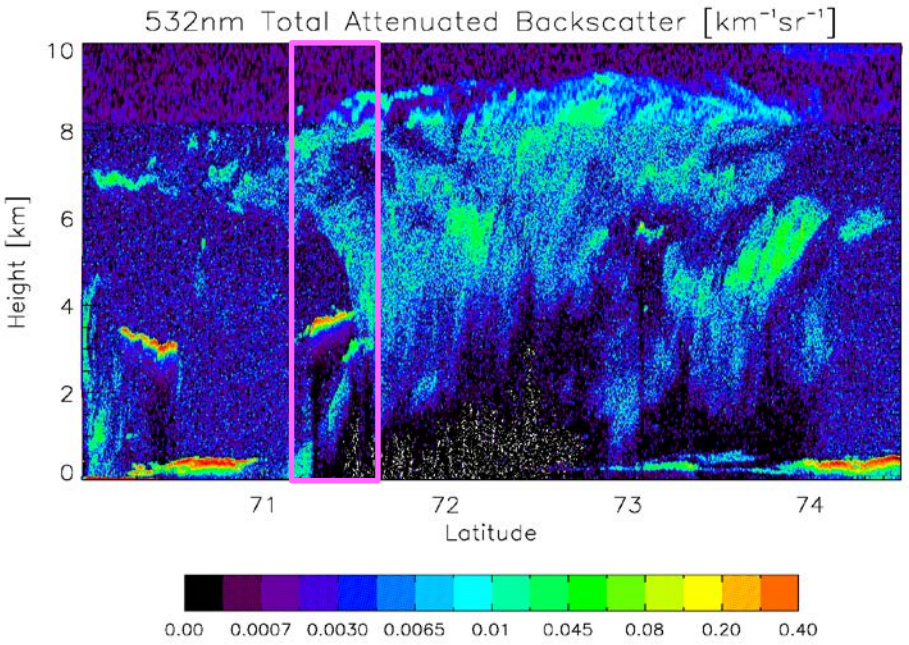
- Comparisons between Ceilometer/Micro-pulse Lidar (MPL) and VIIRS CBHs
- Low clouds (or ice fog) often observed from the ceilometer (below 500 m). When multiple CBHs are available from ground observations, one closer to VIIRS CBH was selected
- **CTH is critical to the CBH accuracy. CBHs from Ceilometer 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

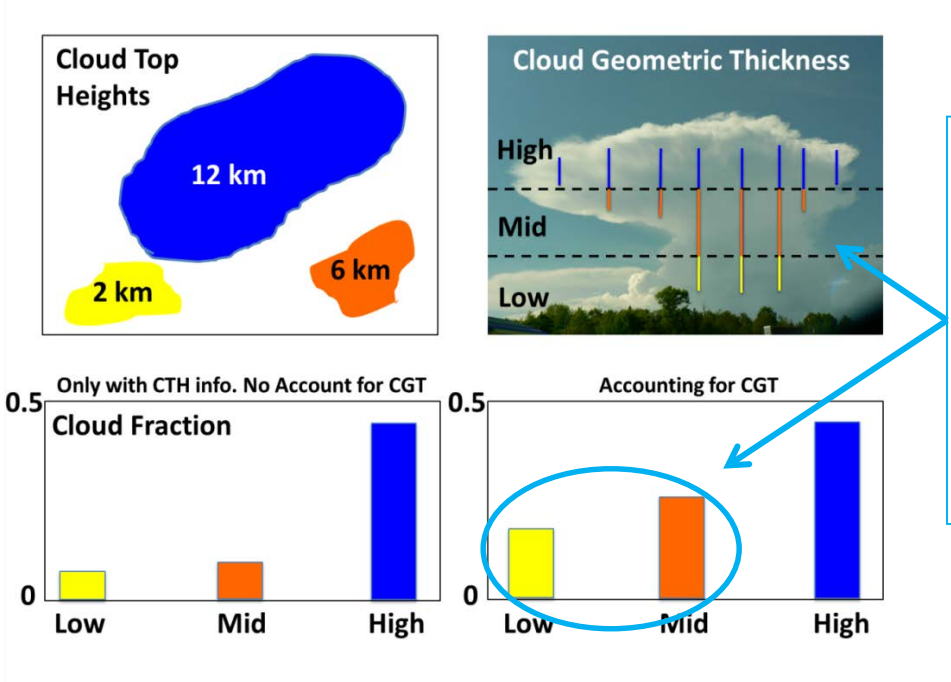








Improvement of Cloud Cover/Layers

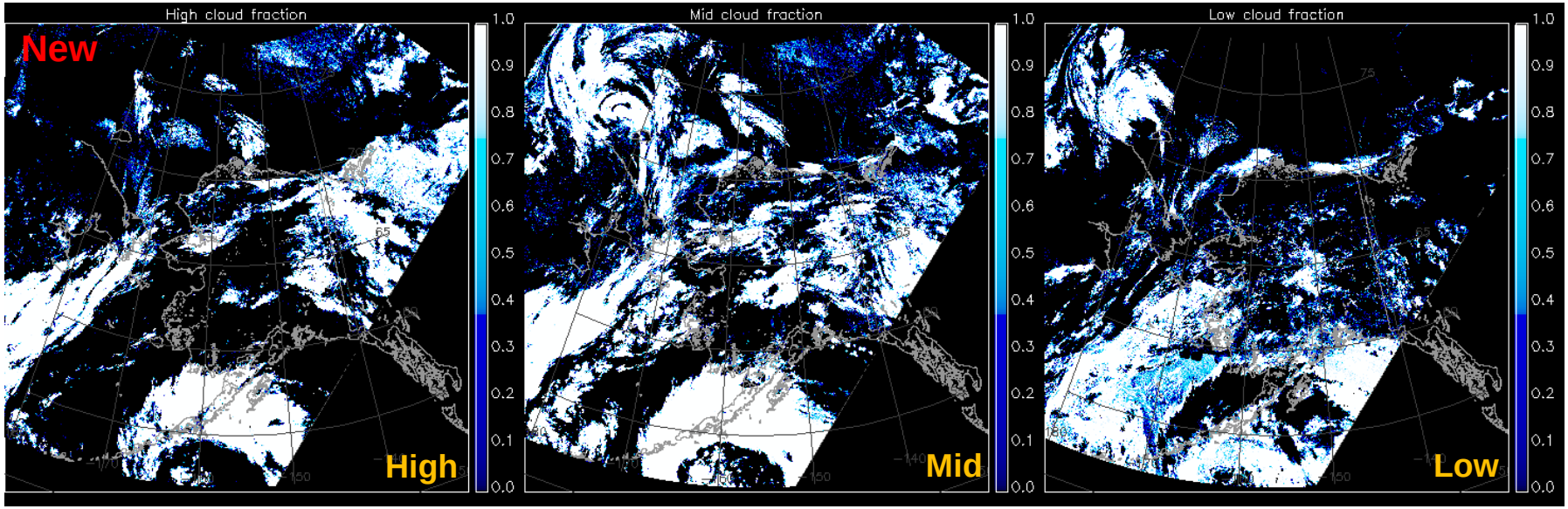


The CBH information can be used to modulate the layered cloud fraction (high/mid/low) by introducing additional cloud coverage at lower (unobserved via satellite) levels of the profile

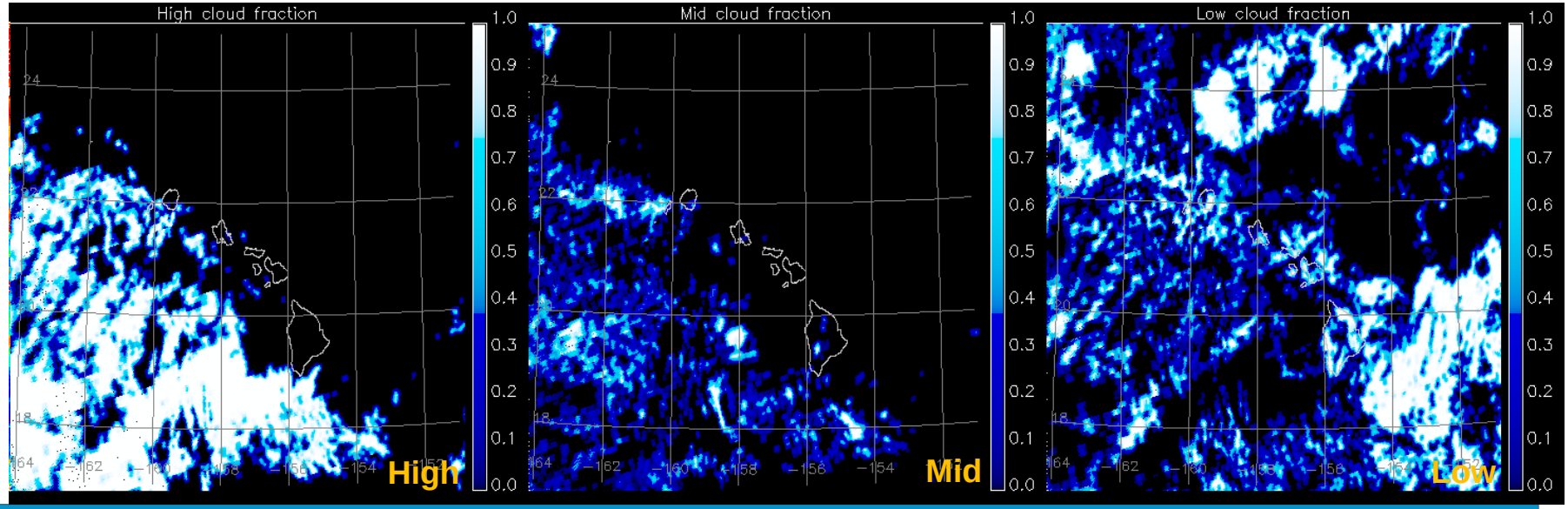
- Implemented the updated algorithm in the CLAVR-x system
  - The current high and low layer thresholds: **350 hPa** and **642 hPa**
  - To be expanded in layers defined by 5 flight levels (NOAT's request)
- Applied to VIIRS (Alaska and Hawaii)
- Applicable to geostationary satellites: Himawari-8 AHI,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

Cloud Cover/Layers over Alaska and Hawaii

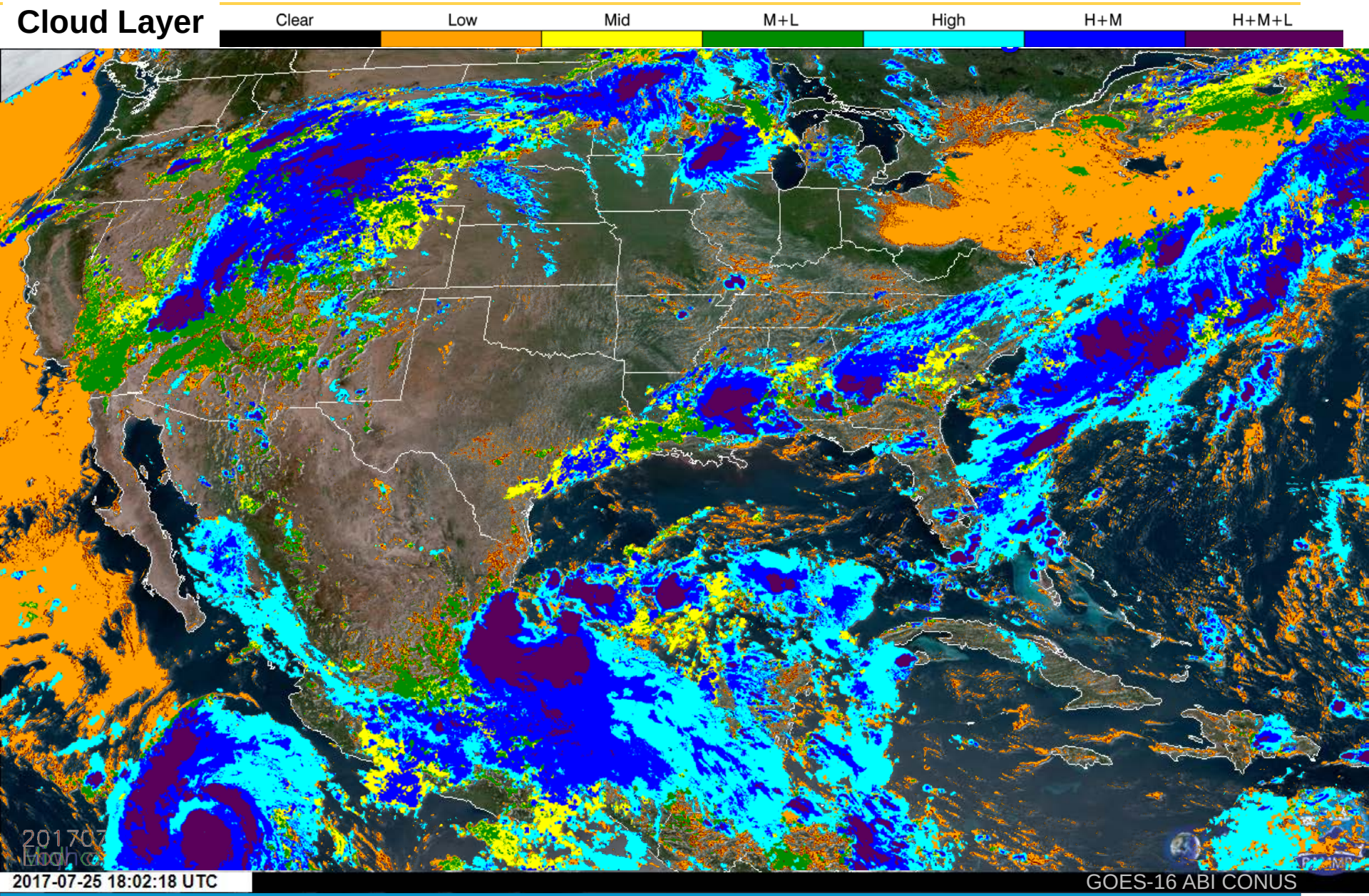
(S-NPP VIIRS 1355 UTC 2016-02-29 **Alaska**) **Increases of Middle and Low Cloud Fractions by using the CBH information**



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

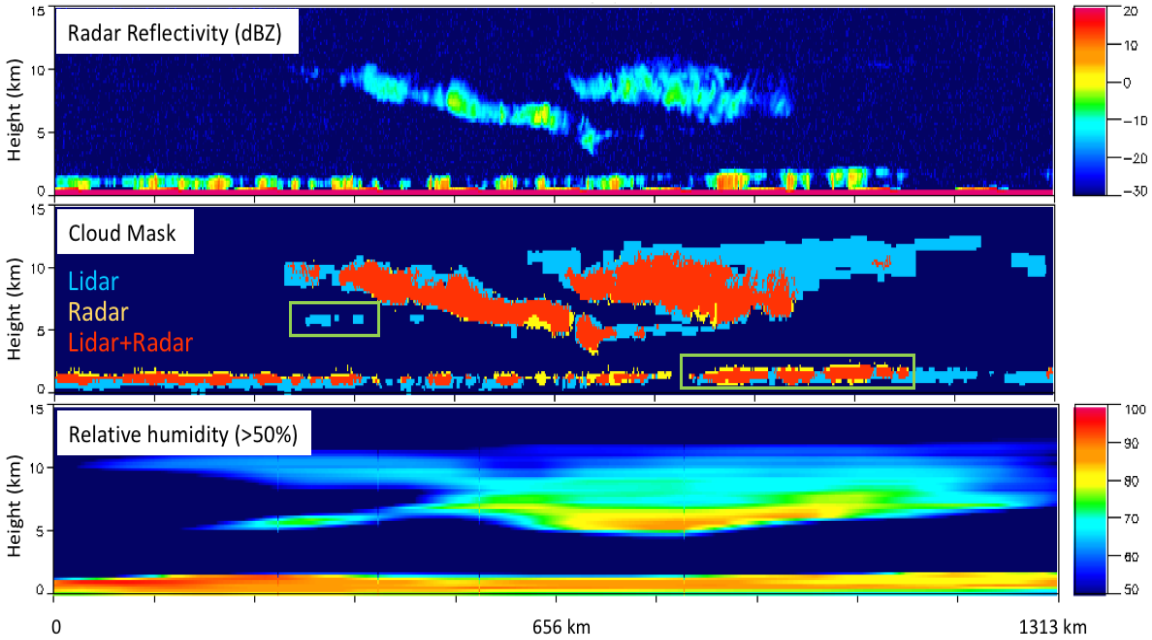


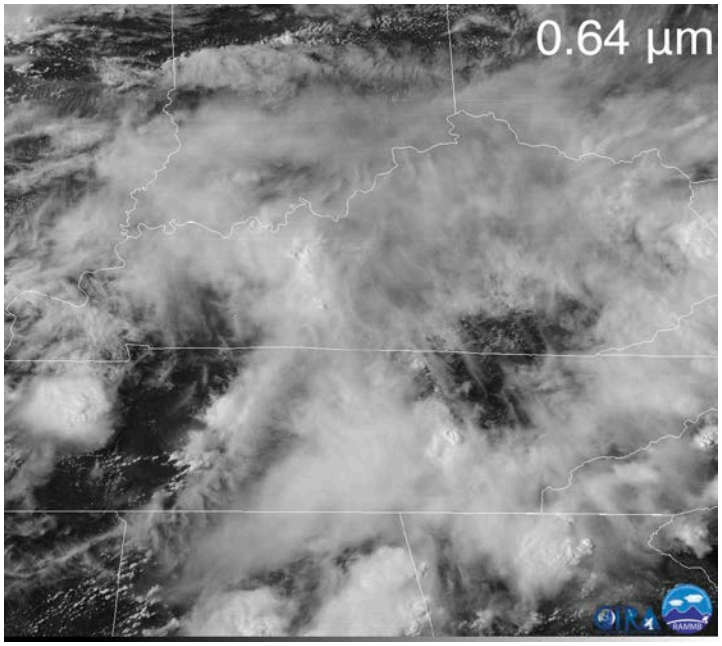
Improvement of Cloud Cover/Layers



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



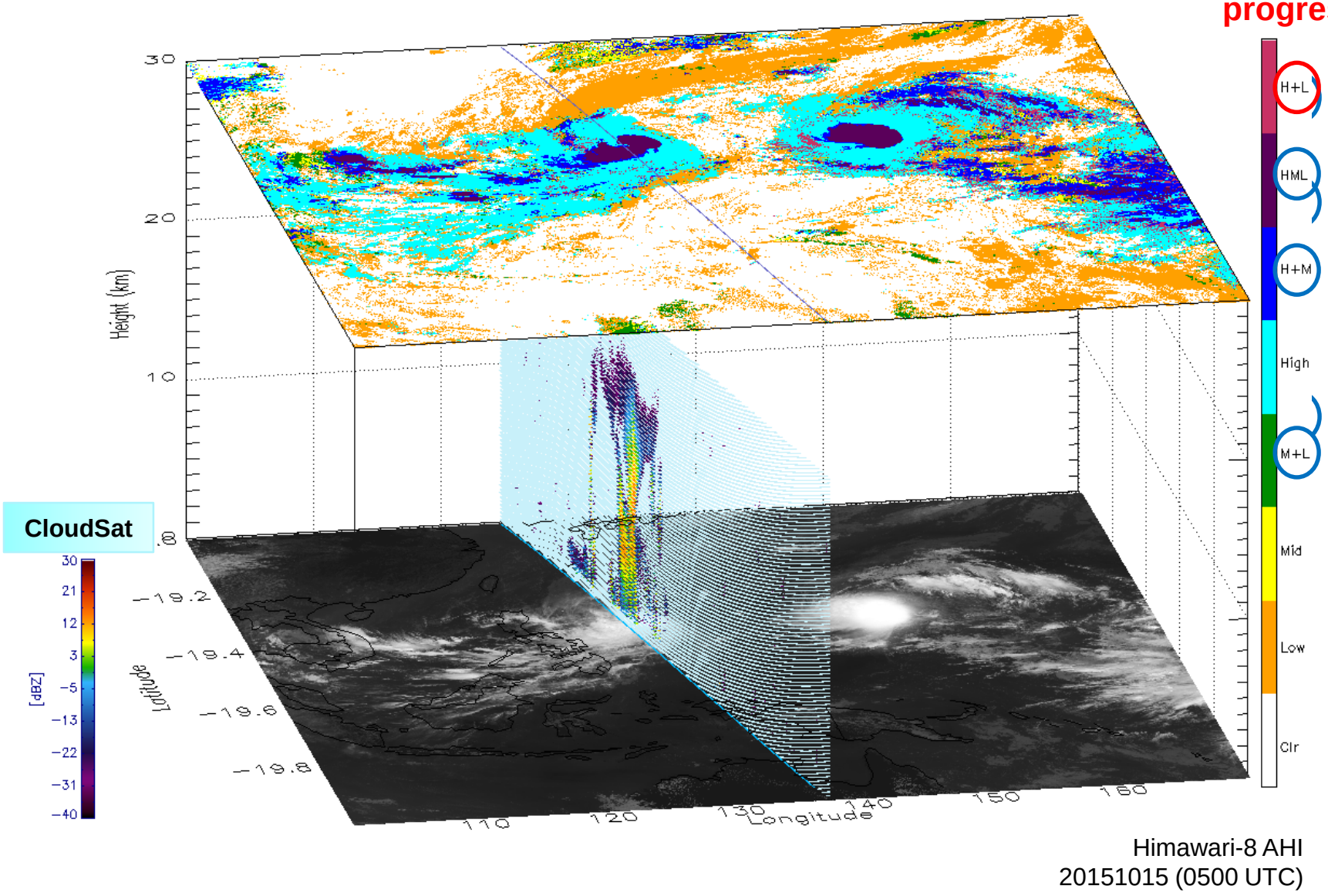


- Use a multi-spectral approach to aid in determination of separation distance between cloud layers
  - 1.38 µm cirrus channel is in a WV absorption band: most reflectance originates from cirrus
  - 0.64 µm red channel is sensitive to upper and lower clouds

Improvement of Cloud Cover/Layers

Validation of Cloud Cover/Layers with CloudSat

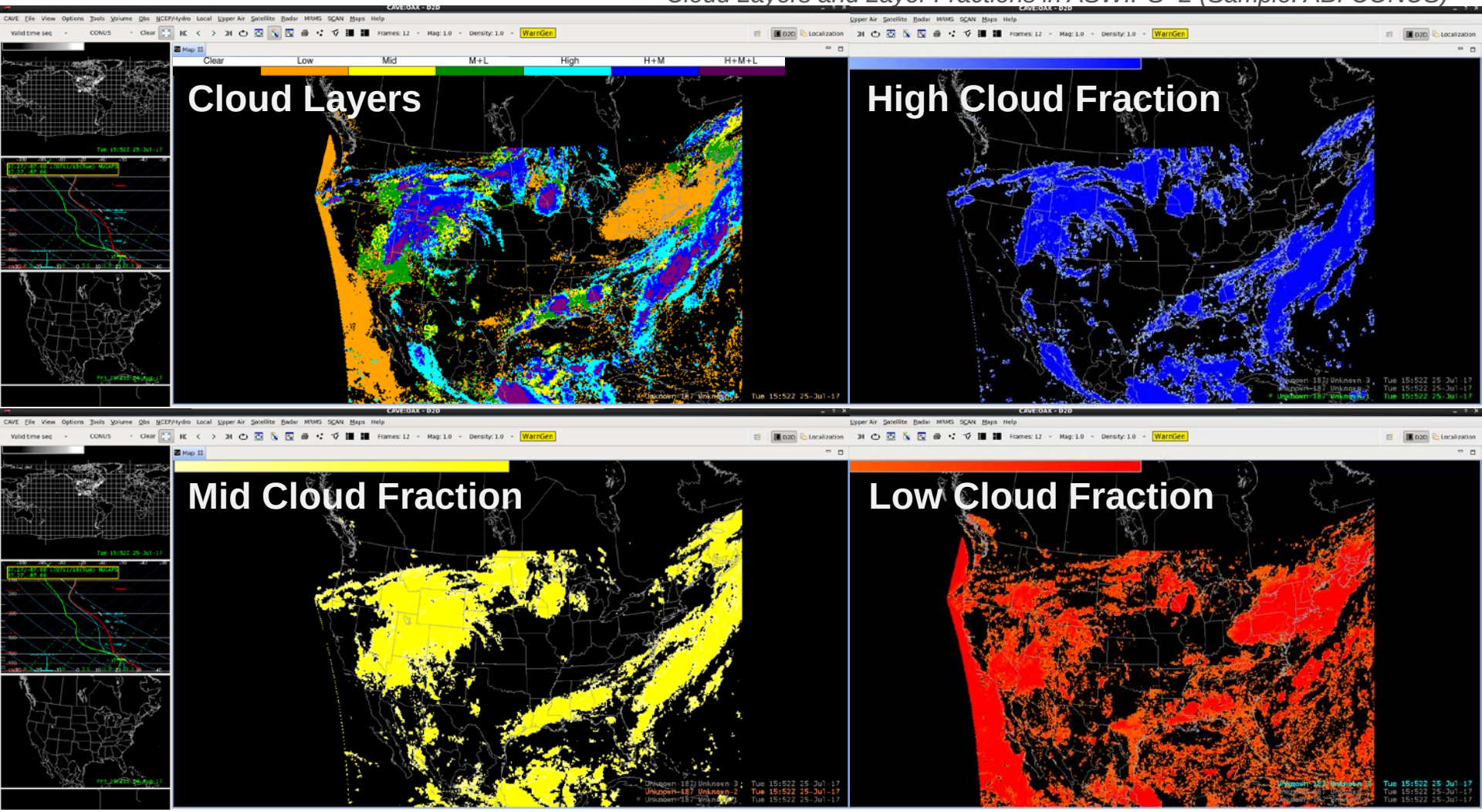
Work in progress



Himawari-8 AHI
20151015 (0500 UTC)

Sample CCL Display in AWIPS-2

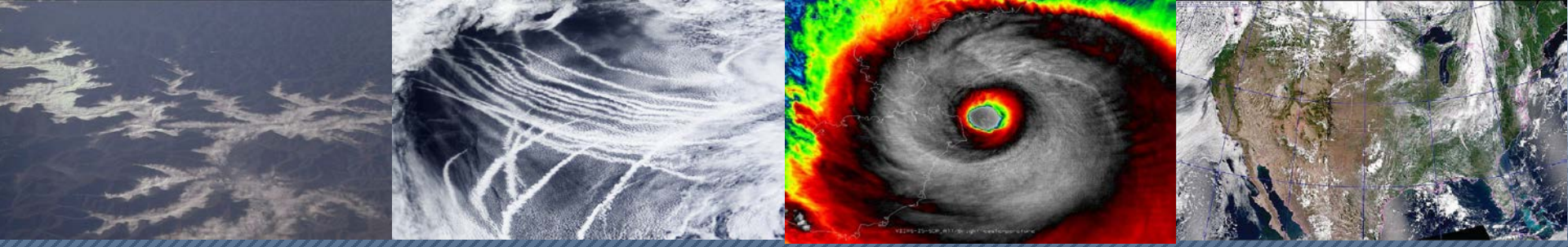
Cloud Layers and Layer Fractions in ASWIPS -2 (Sample: ABI CONUS)



- **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.



VIIRS Cloud Phase and Type Status

Michael J. Pavolonis
NOAA/NESDIS/STAR
Jason Brunner and
Corey Calvert
UW-CIMSS

VIIRS Cloud Phase/Type Products in NDE - Requirements

Name	User & Priority	Geographic Coverage	Vertical Res.	Horiz. Res.	Msmnt. Range	Msmnt. Accuracy	Data Latency	Refresh Rate	Timeliness
Cloud Top Phase	JPSS	Global	Cloud Top	0.75 km	Liquid/solid/ super cooled/mixed (6 categories)	80% correct classification	30 minutes after granule is available	90 minutes	≤ 3 hours

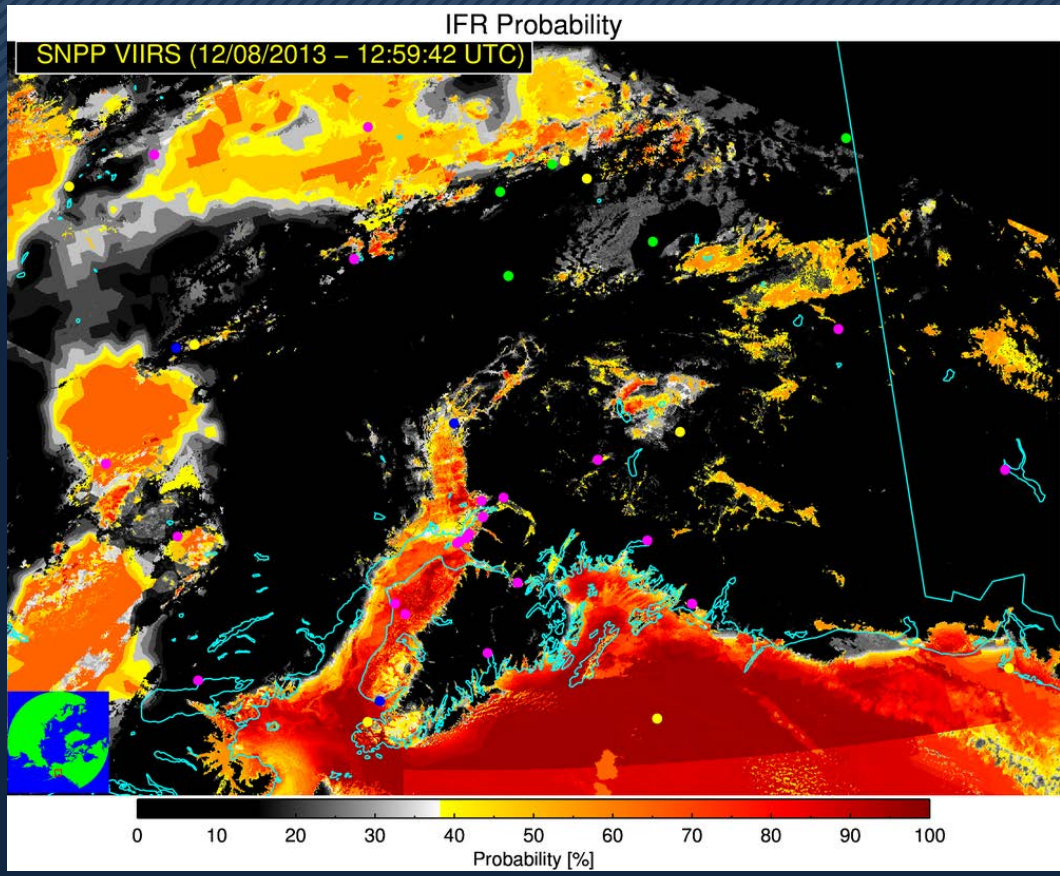
Name	User & Priority	Geographic Coverage	Vertical Res.	Horiz. Res.	Msmnt. Range	Msmnt. Accuracy	Data Latency	Refresh Rate	Timeliness
Cloud Type	JPSS	Global	Cloud Top	0.75 km	7 categories	60% correct classification	30 minutes after granule is available	90 minutes	≤ 3 hours

Algorithm: Pavolonis (2010) and Enterprise Cloud Phase and Type ATBD

VIIRS Cloud Phase/Type Products in NDE - Applications

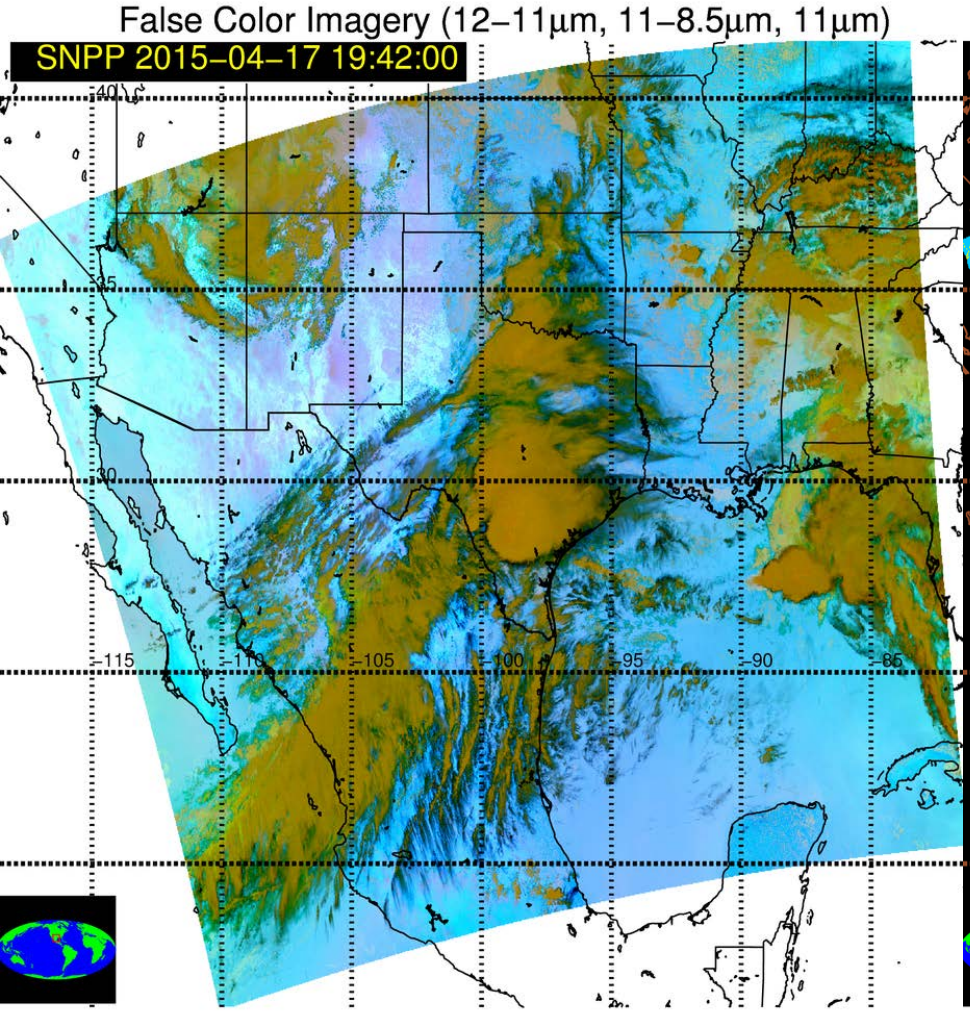
- **Downstream cloud algorithms (cloud height and optical properties)**
- **Aircraft icing**
- **Fog/low stratus (FLS)**
- **Precipitation type**
- **Cloud microphysical studies**

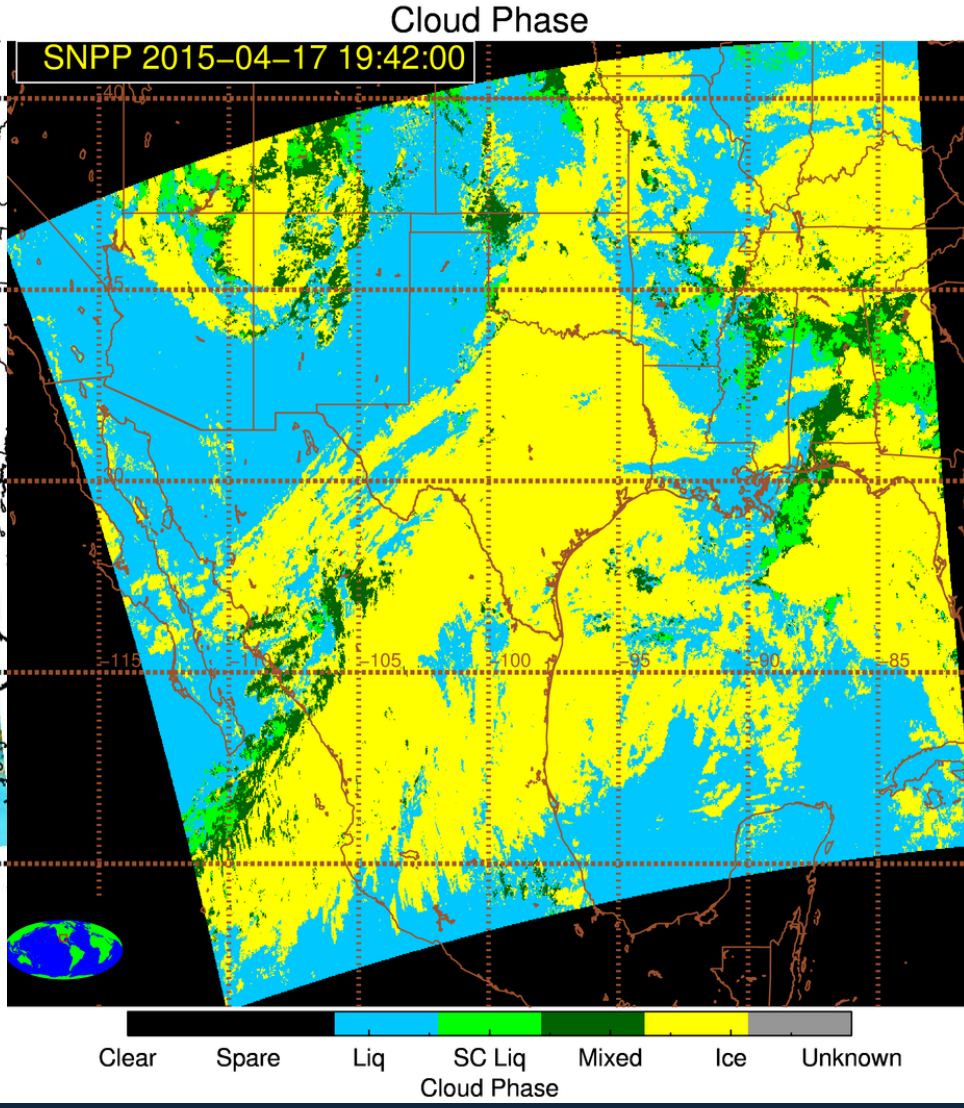
Fog/low stratus threat assessment for aviation



False Color Imagery

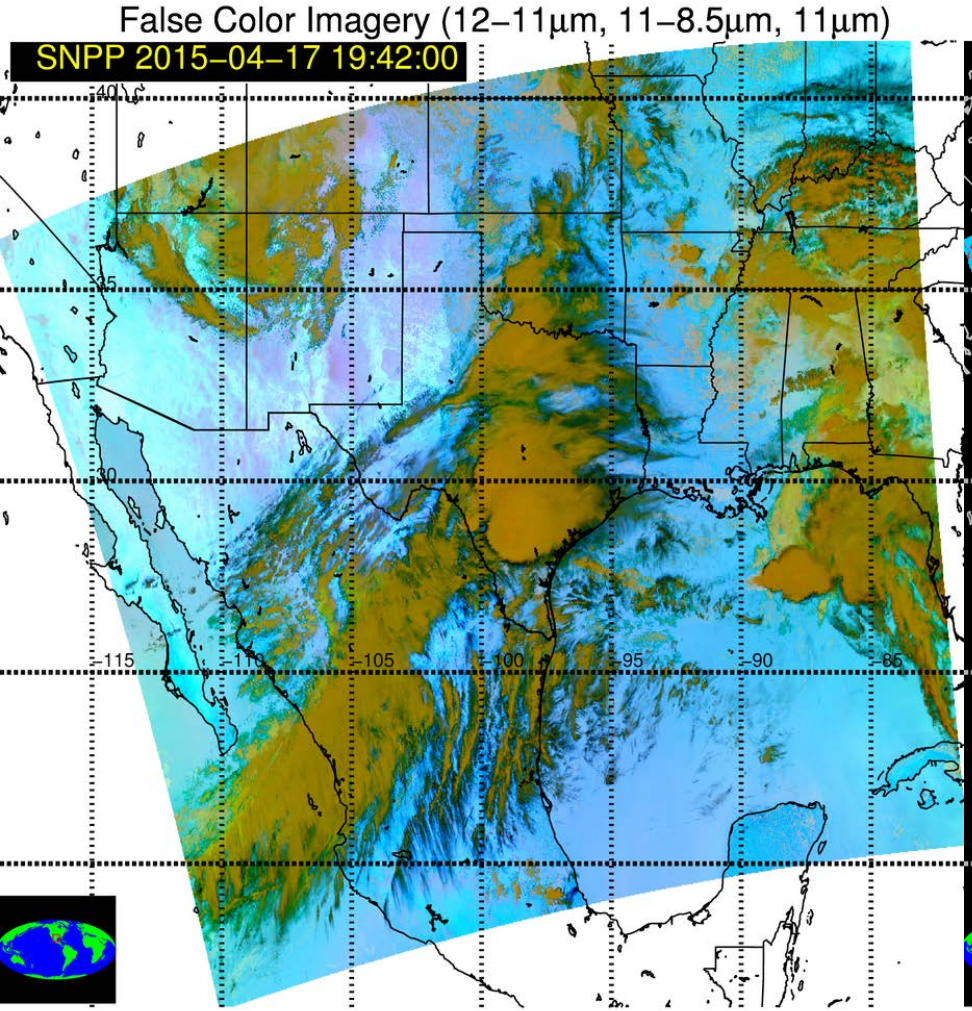
VIIRS NDE Cloud Phase

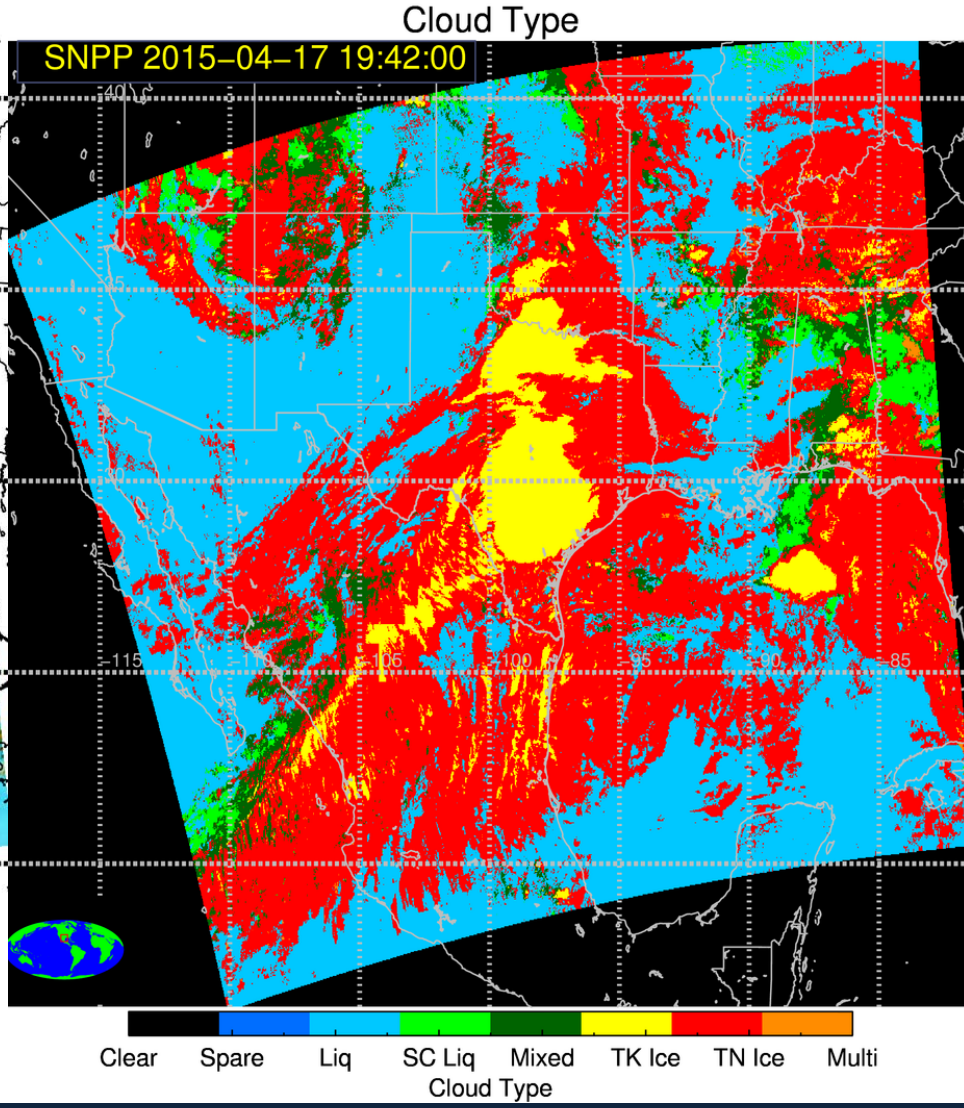




False Color Imagery

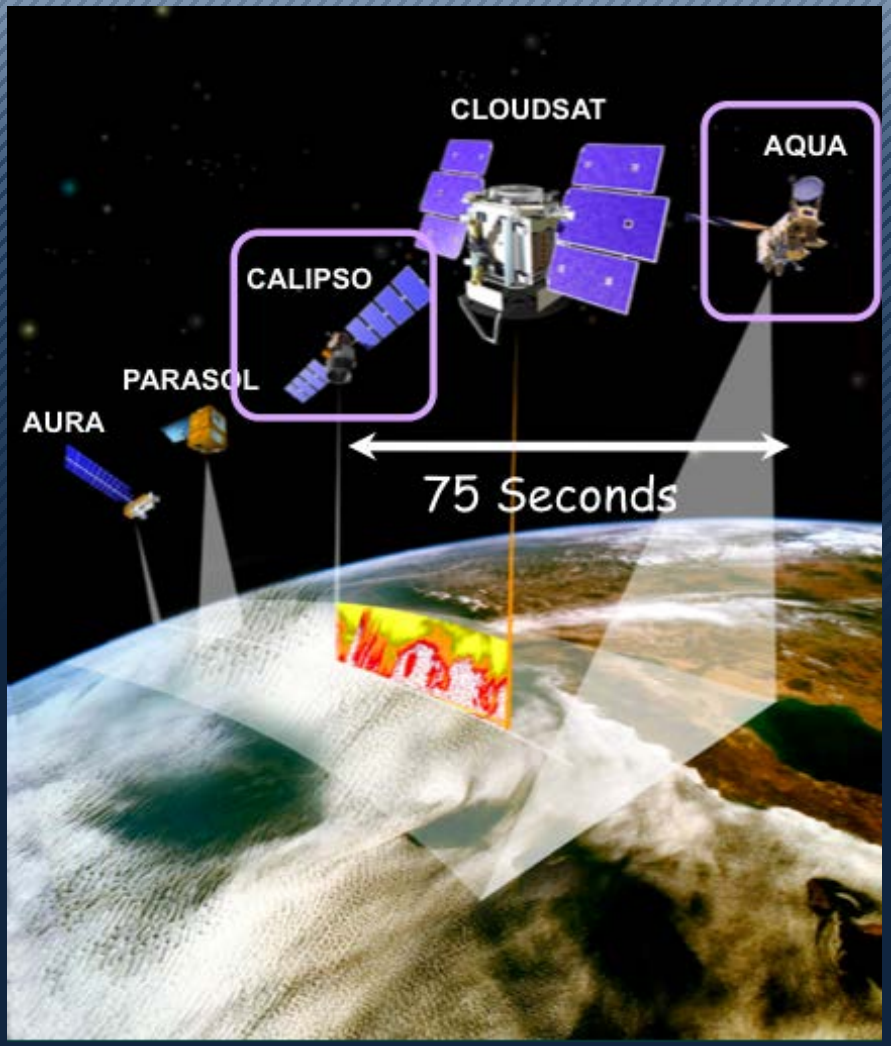
VIIRS NDE Cloud Type

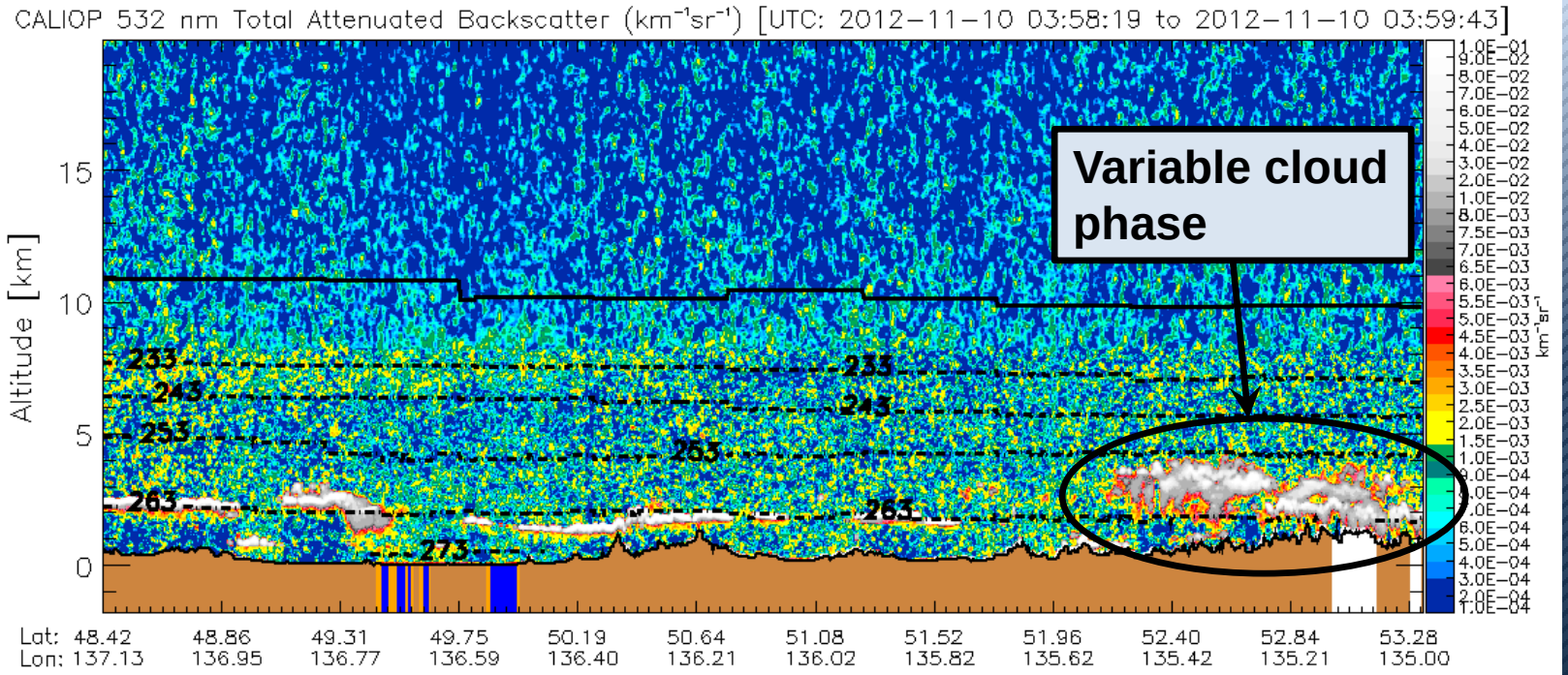


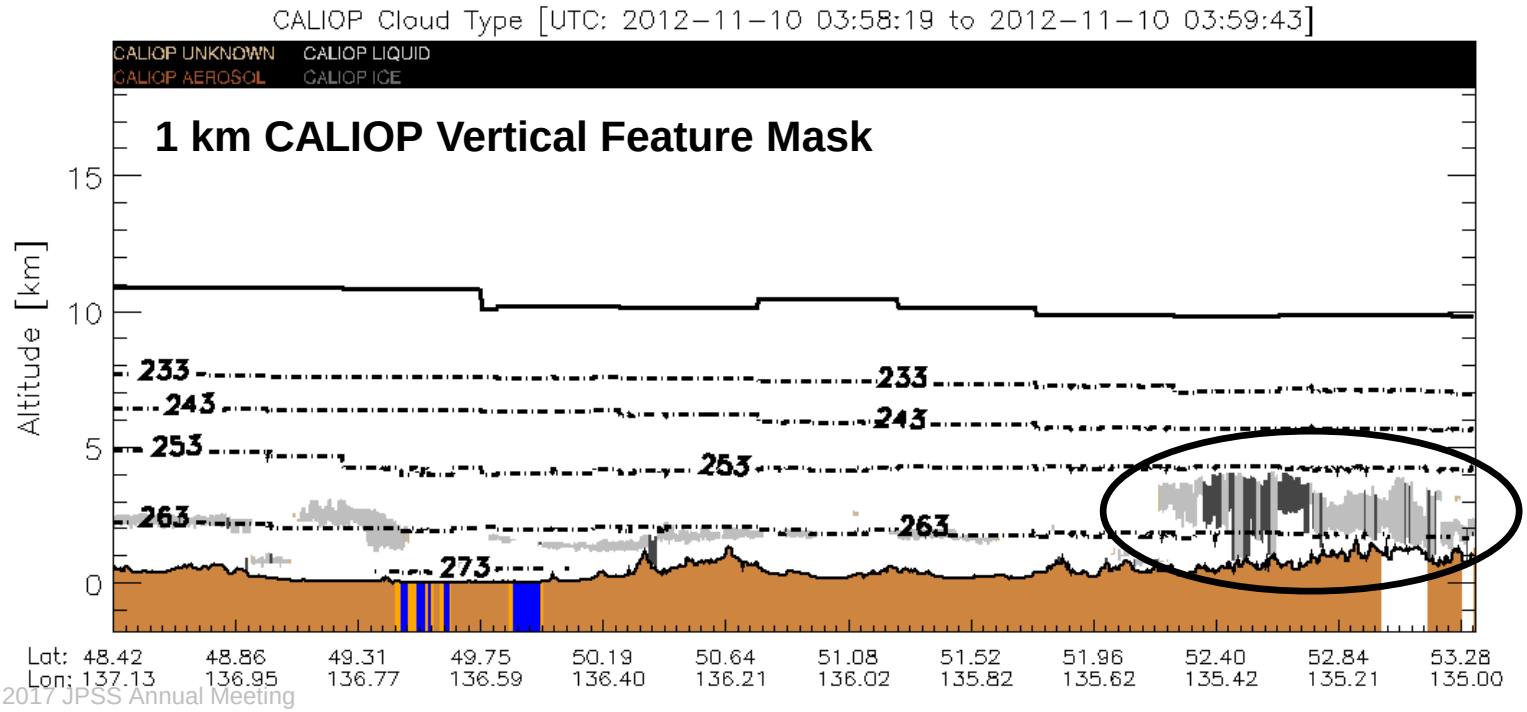


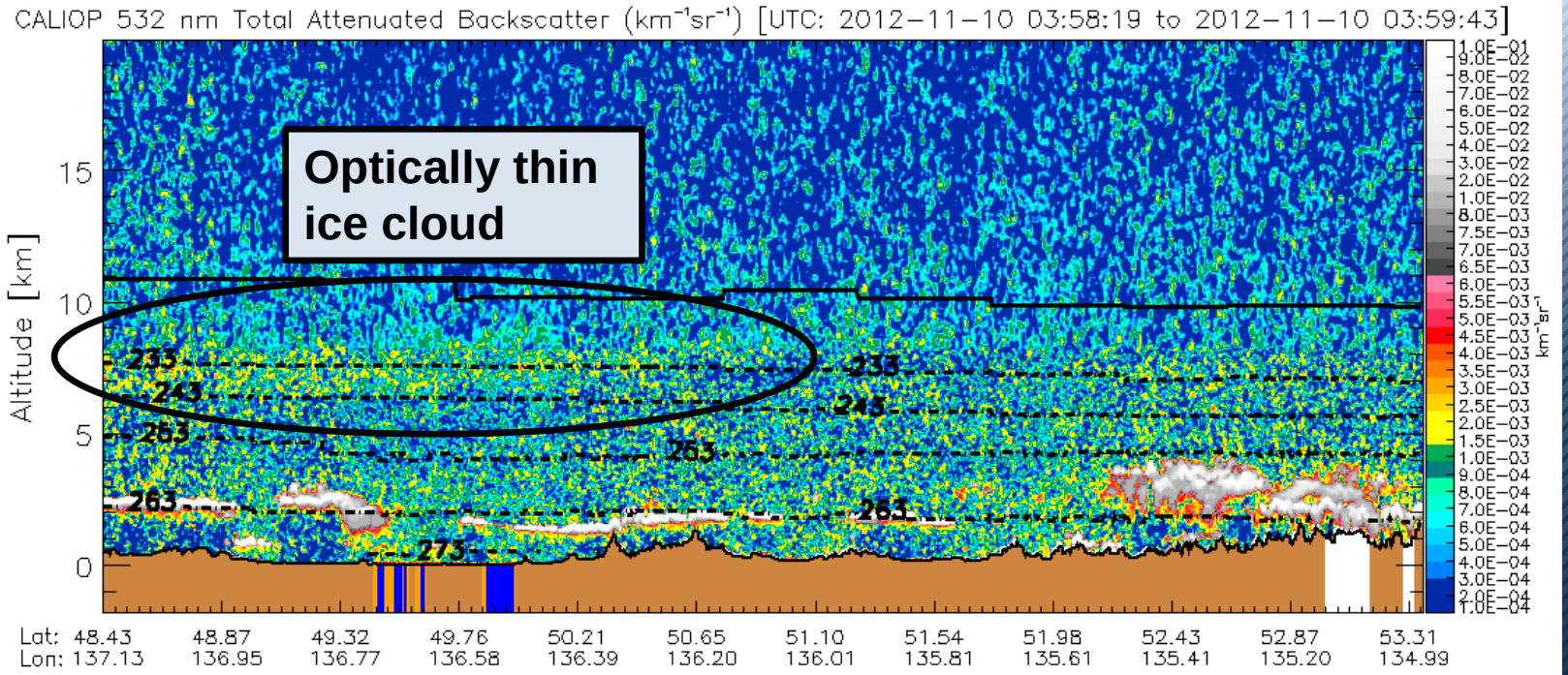
Validation

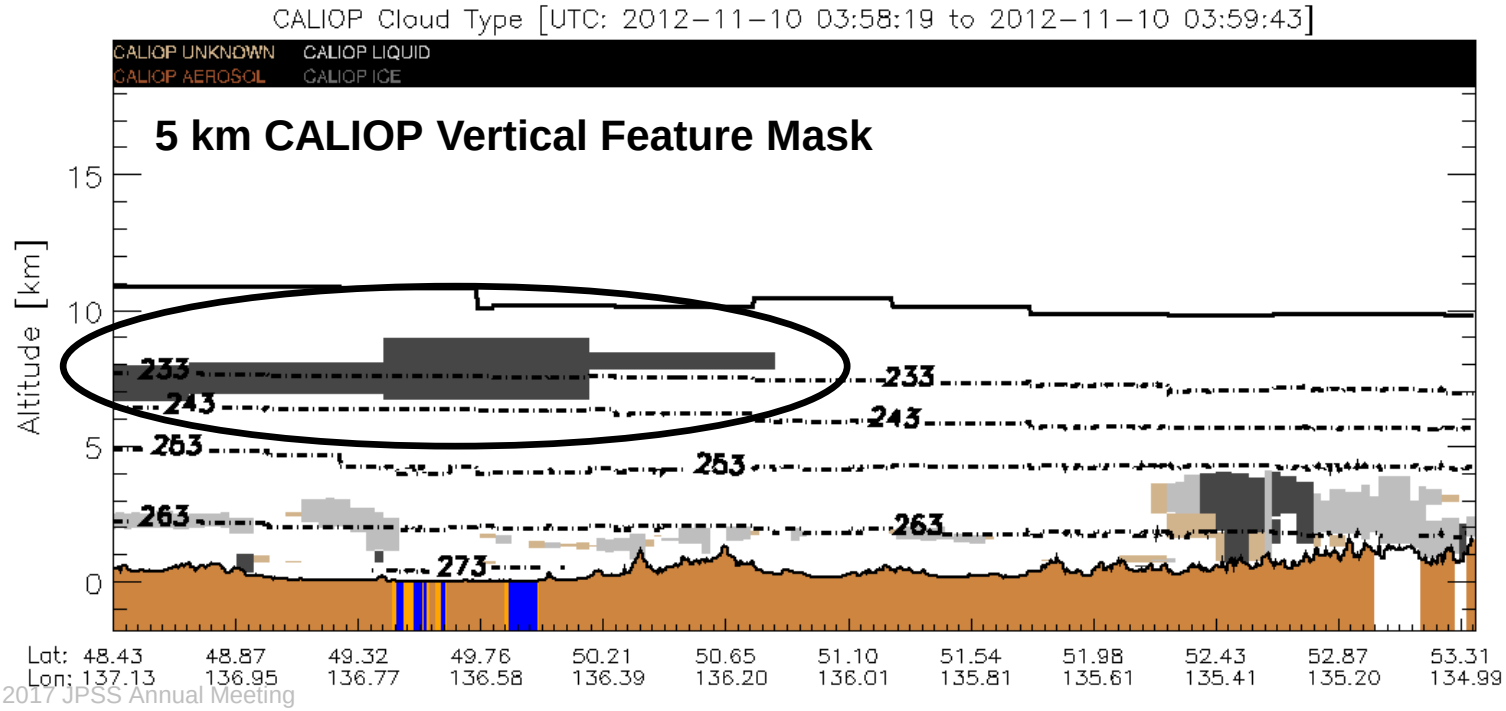
- CALIOP is a lidar, with depolarization, on board the CALIPSO satellite in the NASA A-Train.
- The CALIOP 1 and 5 km vertical feature mask products are merged to derive the cloud phase of the highest cloud layer with CALIOP 532 nm optical depth > 0.01
- Validation analysis is a function of the CALIOP 532 nm cloud optical depth




CALIOP 532 nm Total Attenuated Backscatter (km⁻¹sr⁻¹) [UTC: 2012-11-10 03:58:19 to 2012-11-10 03:59:43]
Variable cloud phase
Altitude [km]
15
10
5
0
233
243
253
263
273
Lat: 48.42 48.86 49.31 49.75 50.19 50.64 51.08 51.52 51.96 52.40 52.84 53.28
Lon: 137.13 136.95 136.77 136.59 136.40 136.21 136.02 135.82 135.62 135.42 135.21 135.00


CALIOP Cloud Type [UTC: 2012-11-10 03:58:19 to 2012-11-10 03:59:43]
CALIOP UNKNOWN
CALIOP LIQUID
CALIOP AEROSOL
CALIOP ICE
1 km CALIOP Vertical Feature Mask
Altitude [km]
15
10
5
0
233
243
253
263
273
Lat: 48.42 48.86 49.31 49.75 50.19 50.64 51.08 51.52 51.96 52.40 52.84 53.28
Lon: 137.13 136.95 136.77 136.59 136.40 136.21 136.02 135.82 135.62 135.42 135.21 135.00


CALIOP 532 nm Total Attenuated Backscatter (km⁻¹sr⁻¹) [UTC: 2012-11-10 03:58:19 to 2012-11-10 03:59:43]
Optically thin ice cloud
Altitude [km]
15
10
5
0
233
243
263
273
Lat: 48.43 48.87 49.32 49.76 50.21 50.65 51.10 51.54 51.98 52.43 52.87 53.31
Lon: 137.13 136.95 136.77 136.58 136.39 136.20 136.01 135.81 135.61 135.41 135.20 134.99


CALIOP Cloud Type [UTC: 2012-11-10 03:58:19 to 2012-11-10 03:59:43]
CALIOP UNKNOWN
CALIOP LIQUID
CALIOP AEROSOL
CALIOP ICE
5 km CALIOP Vertical Feature Mask
Altitude [km]
15
10
5
0
233
243
263
273
Lat: 48.43 48.87 49.32 49.76 50.21 50.65 51.10 51.54 51.98 52.43 52.87 53.31
Lon: 137.13 136.95 136.77 136.58 136.39 136.20 136.01 135.81 135.61 135.41 135.20 134.99

NDE Cloud Phase Validation

Optical Depth Filter

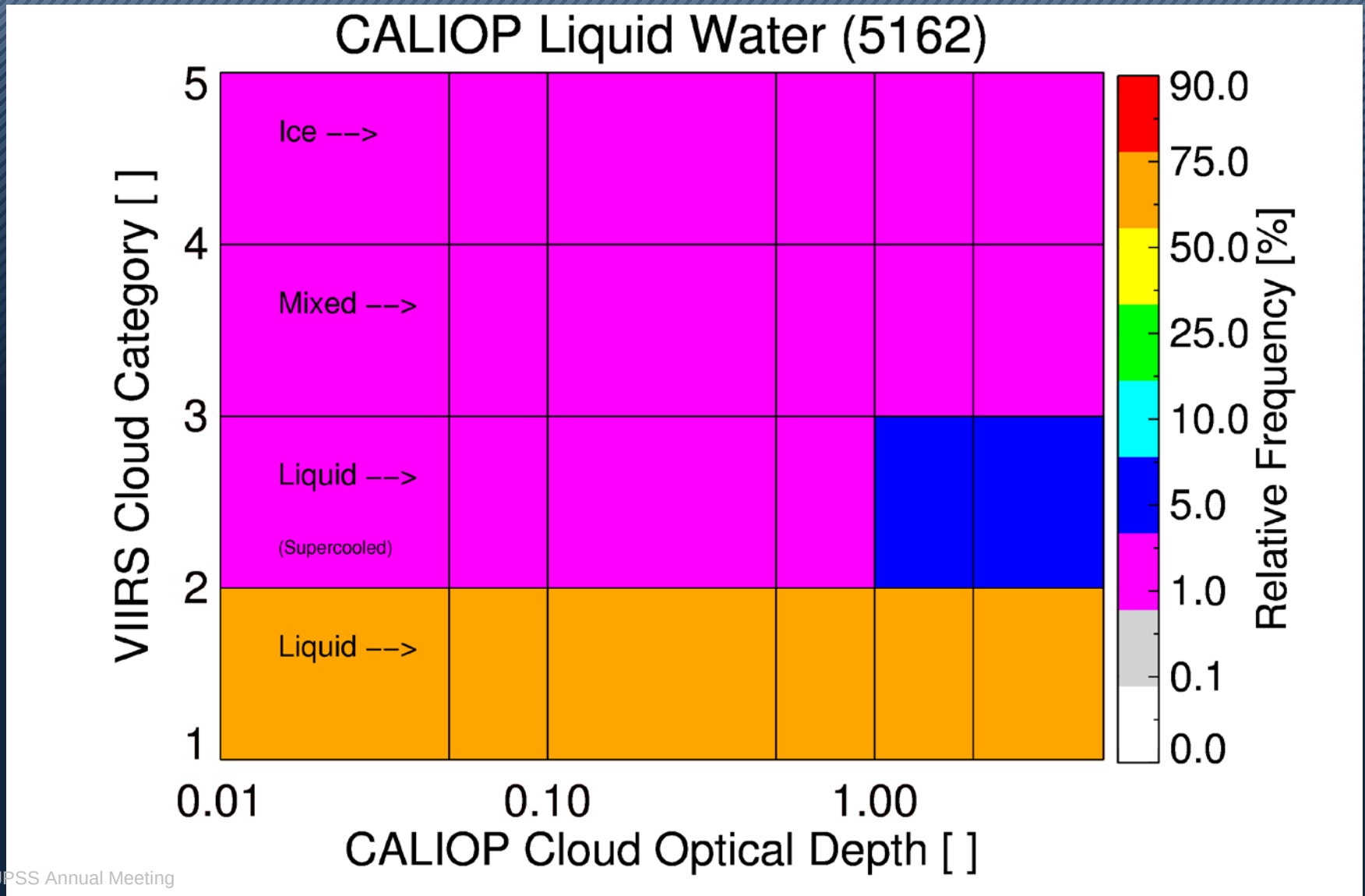
OD	>0.0	>0.1	>0.2	>0.3	>0.4	>0.5	>2.0
All data	0.826 (101144/ 122402)	0.876 (86632/ 98945)	0.882 (78632/ 89122)	0.885 (73889/ 83528)	0.885 (70792/ 79971)	0.885 (68246/ 77090)	0.849 (33375/ 39317)
Day time	0.822 (46123/ 56133)	0.875 (37517/ 42874)	0.881 (33982/ 38585)	0.880 (31653/ 35966)	0.880 (30307/ 34431)	0.880 (29267/ 33240)	0.822 (13703/ 16671)
Night time	0.830 (55021/ 66269)	0.876 (49115/ 56071)	0.884 (44650/ 50537)	0.888 (42236/ 47562)	0.889 (40485/ 45540)	0.889 (38979/ 43850)	0.869 (19672/ 22646)
Over land	0.862 (26242/ 30446)	0.897 (21655/ 24153)	0.904 (19429/ 21487)	0.907 (17766/ 19581)	0.909 (16888/ 18584)	0.910 (16193/ 17796)	0.868 (5999/ 6913)
Over water	0.815 (74902/ 91956)	0.869 (64977/ 74792)	0.875 (59203/ 67635)	0.878 (56123/ 63947)	0.878 (53904/ 61387)	0.878 (52053/ 59294)	0.845 (27376/ 32404)
Lat > 60 deg	0.860 (23218/ 26983)	0.870 (18754/ 21561)	0.873 (17127/ 19612)	0.873 (16046/ 18387)	0.873 (15407/ 17642)	0.872 (14772/ 16949)	0.782 (6264/ 8007)
Lat < 60 deg	0.817 (77926/ 95419)	0.877 (67878/ 77384)	0.885 (61505/ 69510)	0.888 (57843/ 65141)	0.889 (55385/ 62329)	0.889 (53474/ 60141)	0.866 (27111/ 31310)

NDE Cloud Type Validation

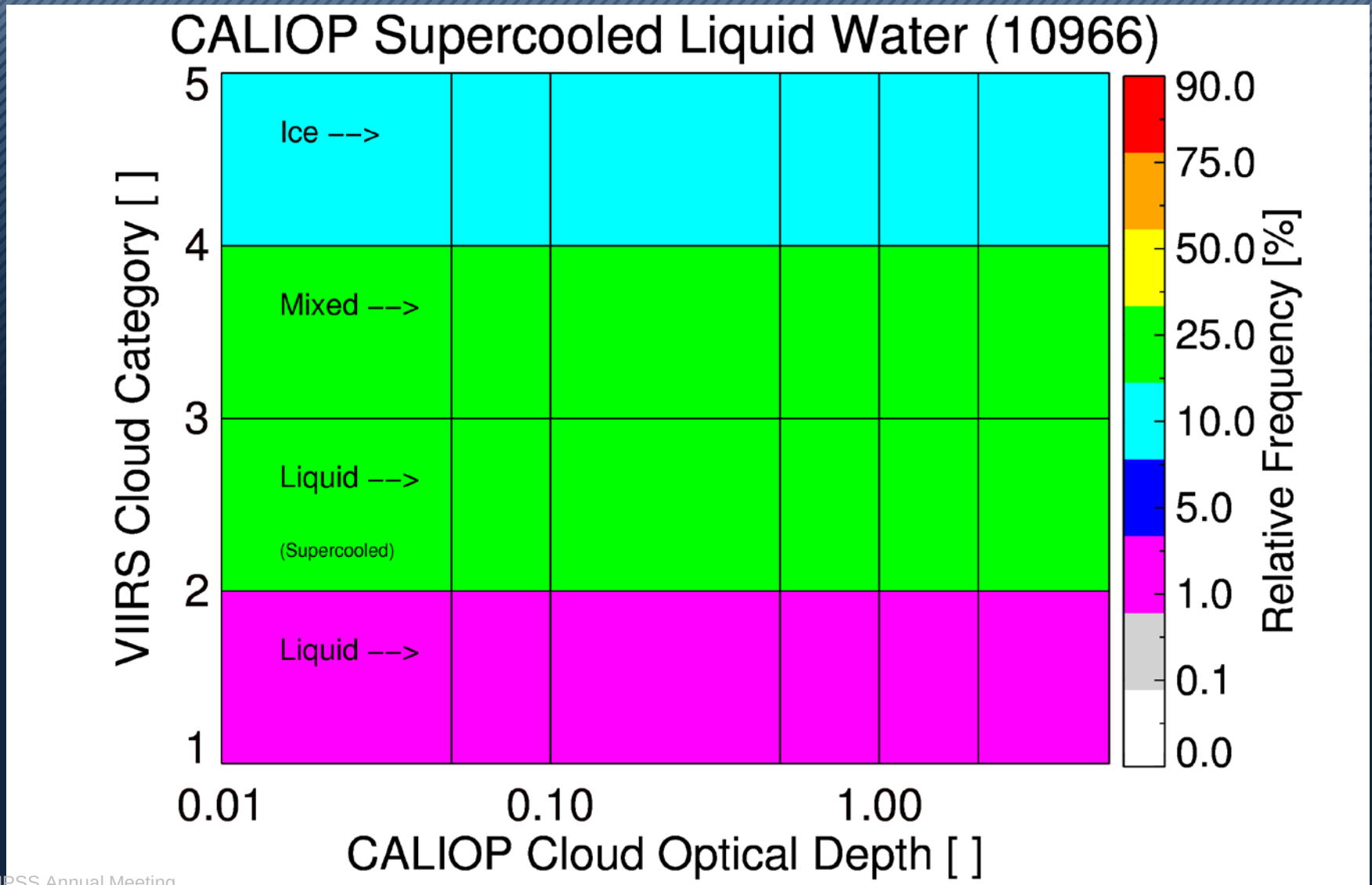
Optical Depth Filter

OD	> 0.0	>0.1	>0.2	>0.3	>0.4	>0.5	>2.0
All data	0.726 (82679/ 113807)	0.778 (71968/ 92555)	0.791 (65841/ 83244)	0.799 (62265/ 77943)	0.802 (59771/ 74539)	0.805 (57802/ 71847)	0.775 (28372/ 36601)
Day time	0.712 (35328/ 49614)	0.775 (29527/ 38104)	0.790 (27015/ 34180)	0.797 (25307/ 31770)	0.799 (24247/ 30357)	0.803 (23514/ 29293)	0.754 (11044/ 14642)
Night time	0.738 (47351/ 64193)	0.779 (42441/ 54451)	0.791 (38826/ 49064)	0.800 (36958/ 46173)	0.804 (35524/ 44182)	0.806 (34288/ 42554)	0.789 (17328/ 21959)
Over land	0.719 (19737/ 27445)	0.753 (16429/ 21819)	0.760 (14670/ 19315)	0.763 (13393/ 17547)	0.766 (12755/ 16656)	0.768 (12261/ 15965)	0.676 (4118/ 6095)
Over water	0.729 (62942/ 86362)	0.785 (55539/ 70736)	0.800 (51171/ 63929)	0.809 (48872/ 60396)	0.812 (47016/ 57883)	0.815 (45541/ 55882)	0.795 (24254/ 30506)
Lat > 60 deg	0.803 (15903/ 19805)	0.844 (13560/ 16063)	0.865 (12557/ 14514)	0.876 (11874/ 13556)	0.881 (11399/ 12945)	0.884 (10980/ 12426)	0.837 (4846/ 5789)
Lat < 60 deg	0.710 (66776/ 94002)	0.764 (58408/ 76492)	0.775 (53284/ 68730)	0.783 (50391/ 64387)	0.785 (48372/ 61594)	0.788 (46822/ 59421)	0.764 (23526/ 30812)

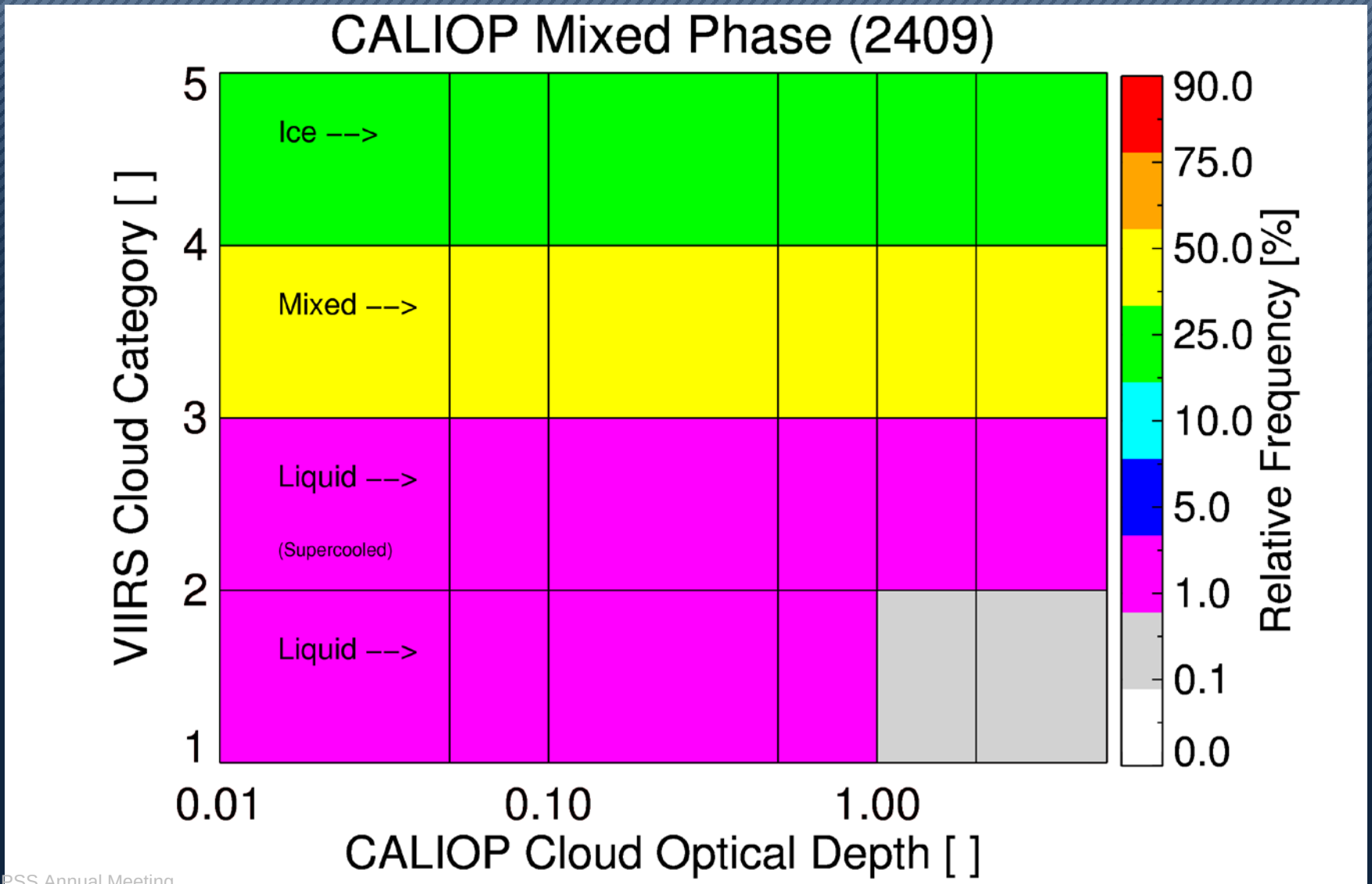
When CALIOP indicates warm liquid water, the VIIRS algorithm generally agrees (most disagreements fall into supercooled liquid water category)



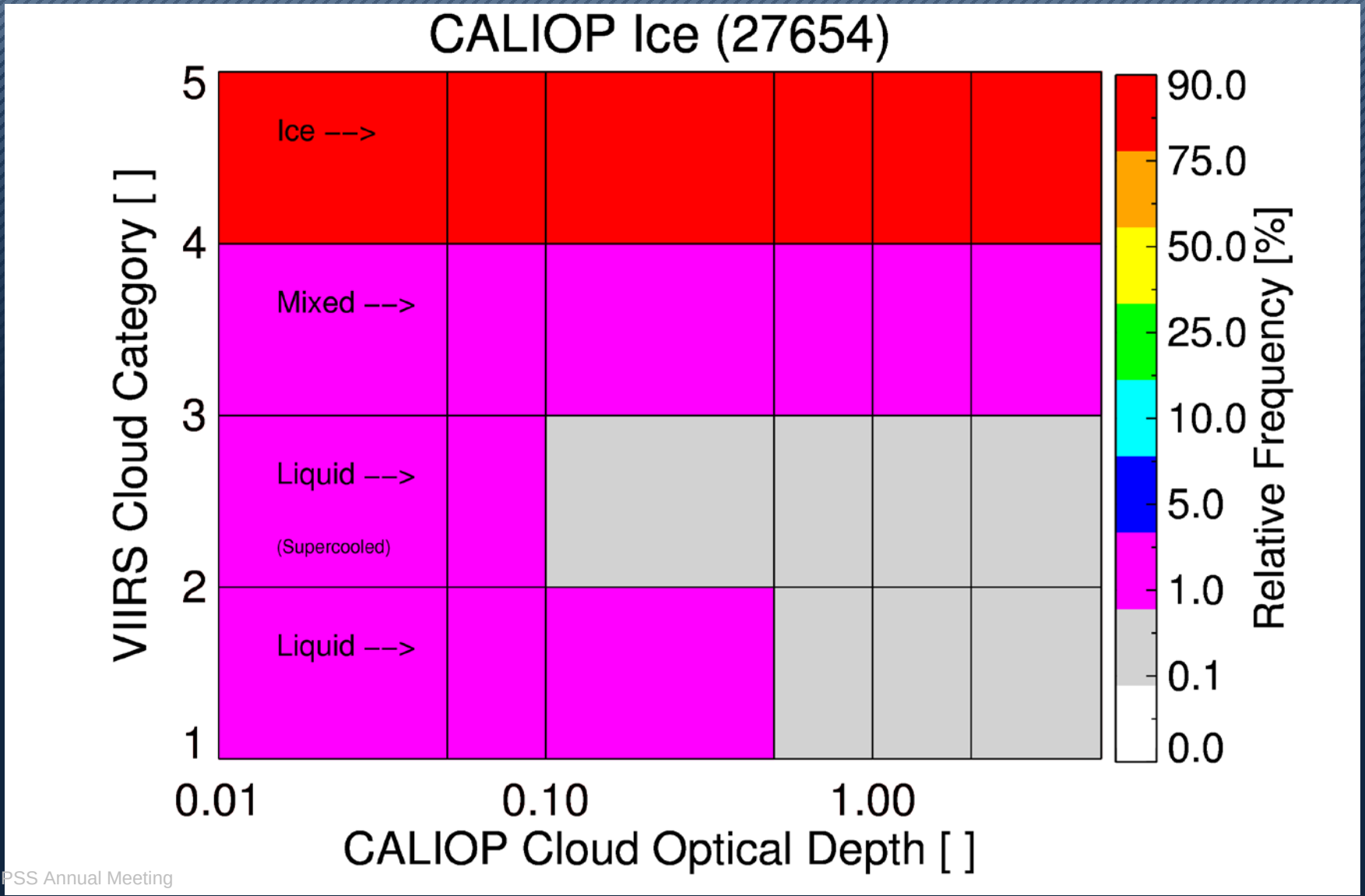
When CALIOP indicates supercooled liquid water, the VIIRS algorithm generally classifies clouds as supercoooled liquid or mixed phase



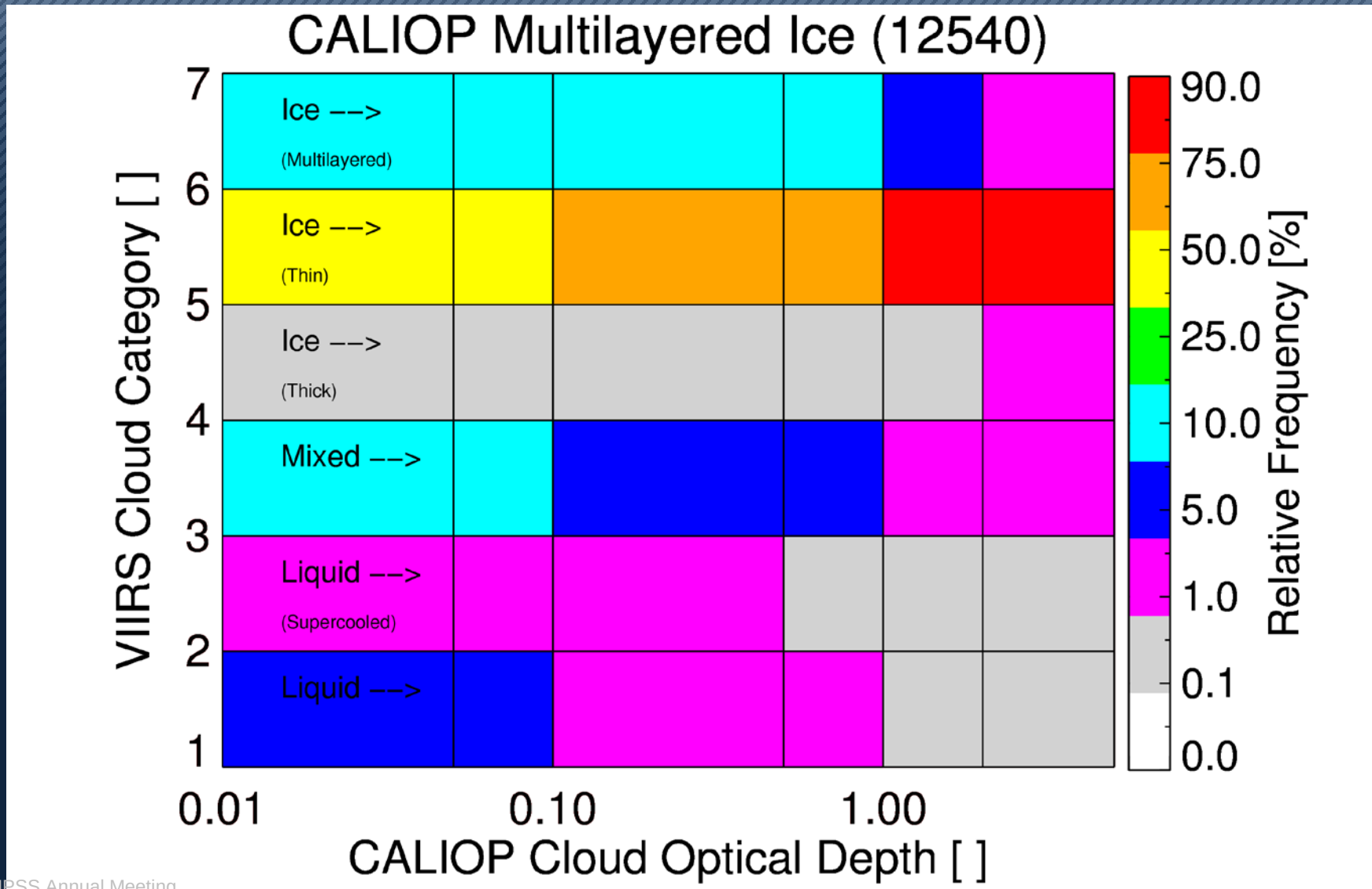
When CALIOP indicates mixed phase, the VIIRS algorithm generally agrees (most disagreements fall into ice phase category)



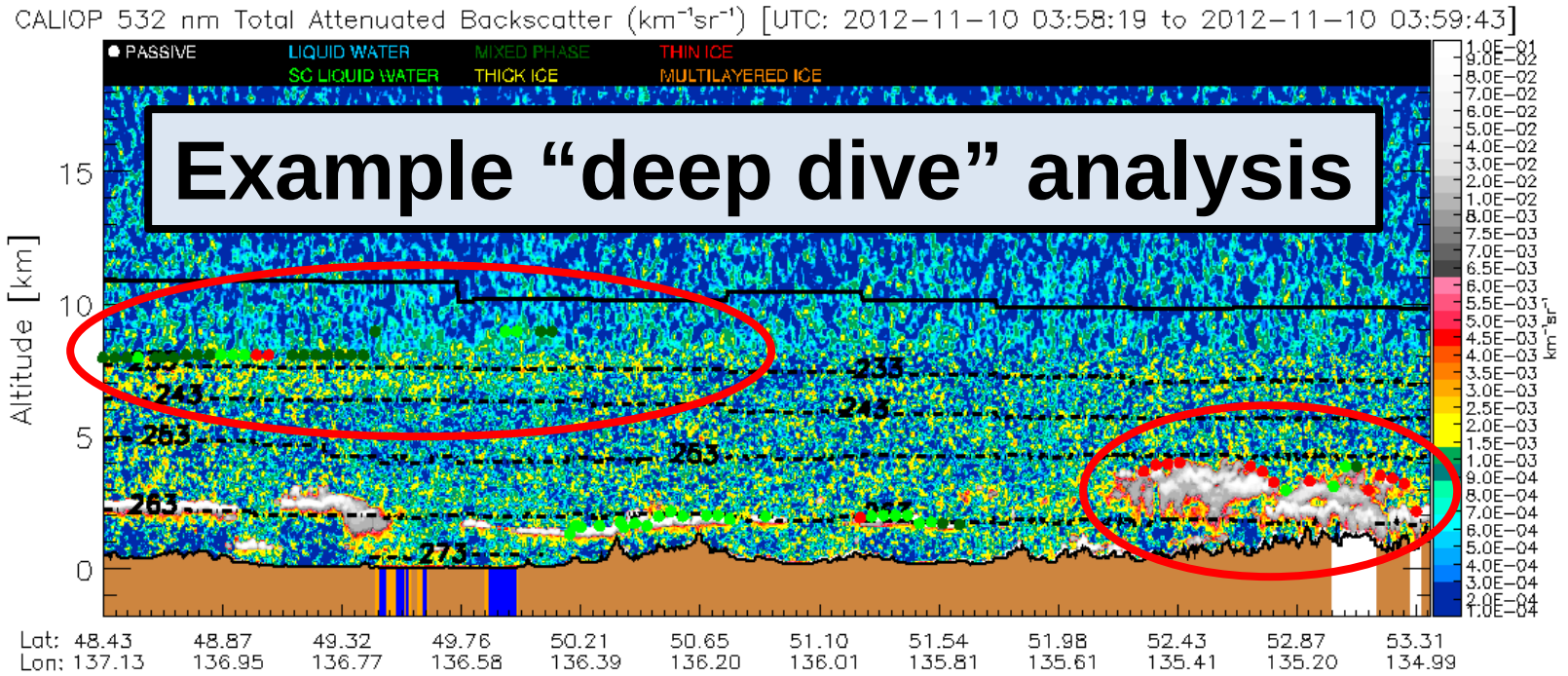
When CALIOP indicates ice phase, the VIIRS algorithm generally agrees (most disagreements fall into mixed phase category)

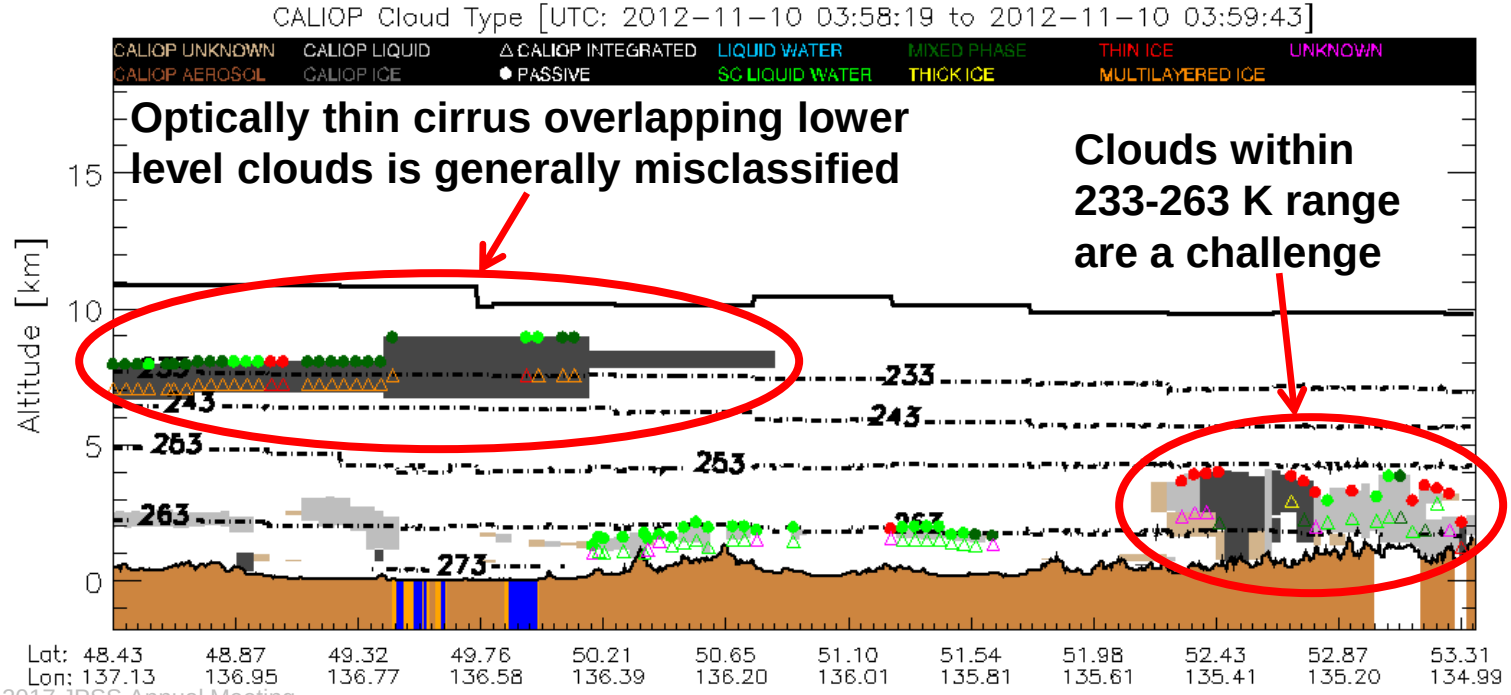


When CALIOP indicates multilayered ice, the VIIRS algorithm has a difficult time identifying the cloud as multilayered ice



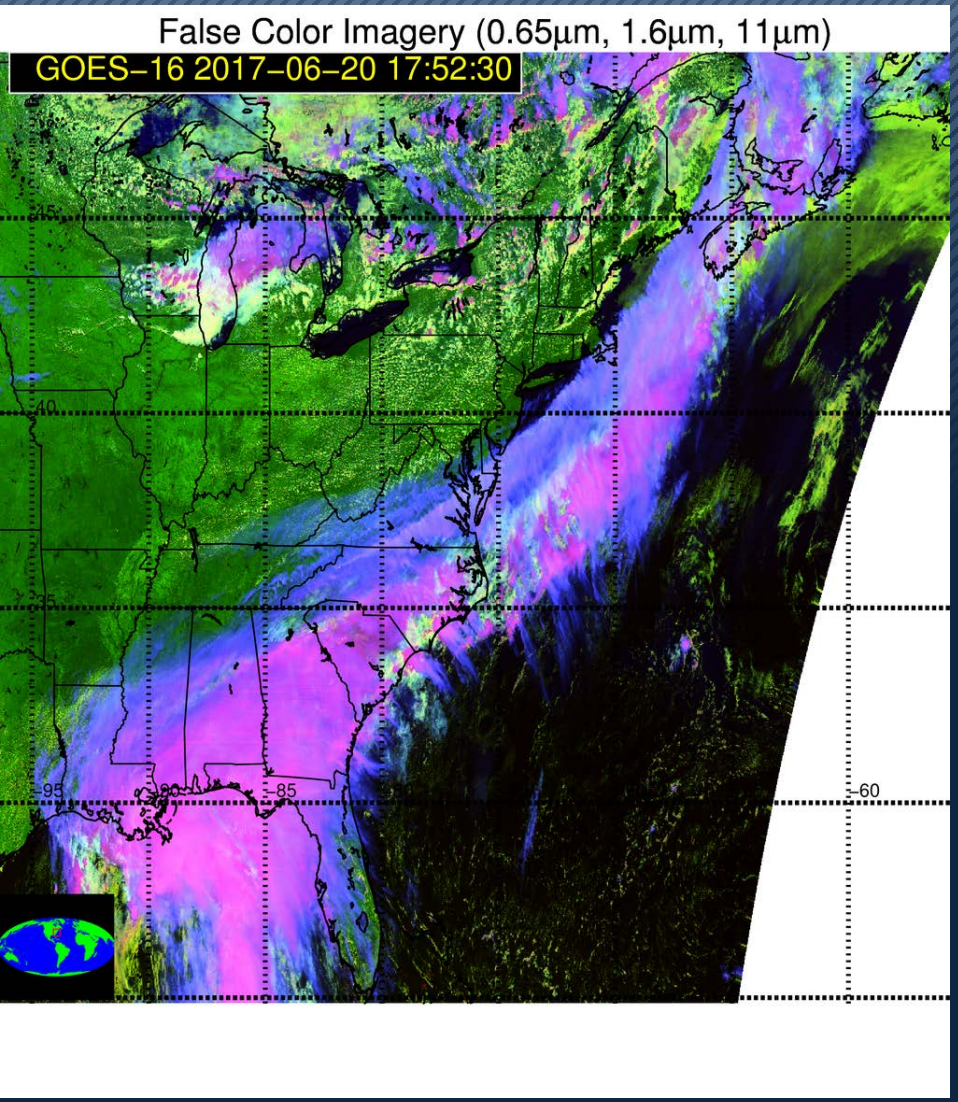
Example “deep dive” analysis



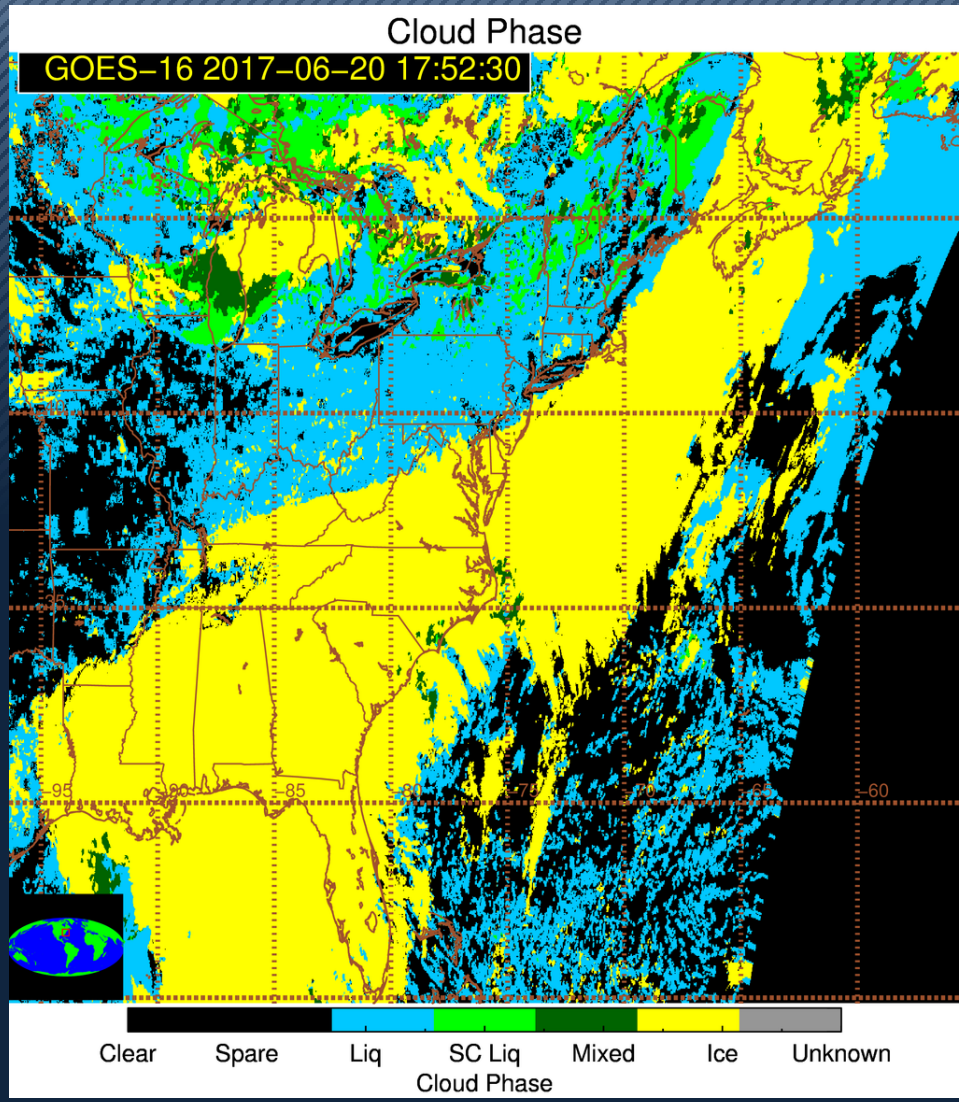


VIIRS NDE vs GOES-16 ABI from GS

False Color Imagery

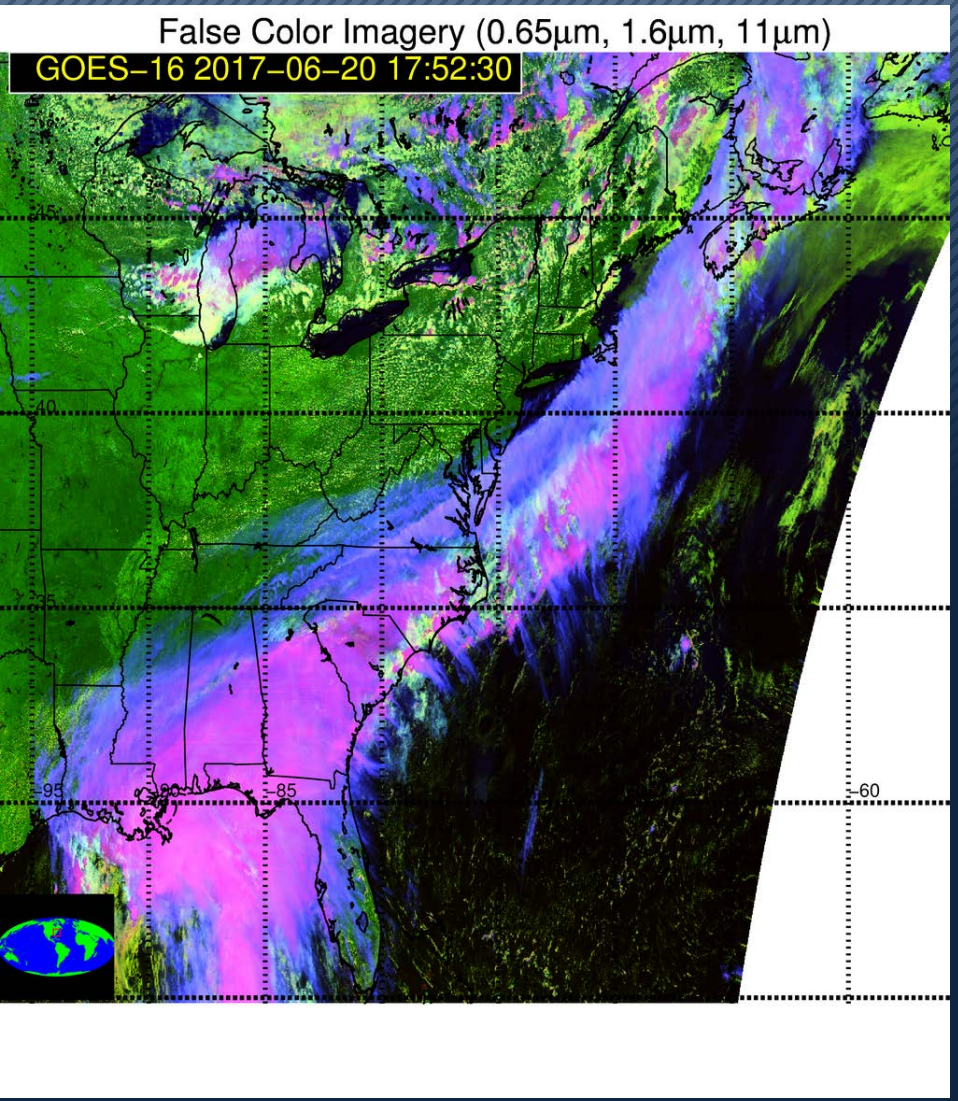


GOES-16 ABI GS Cloud Phase

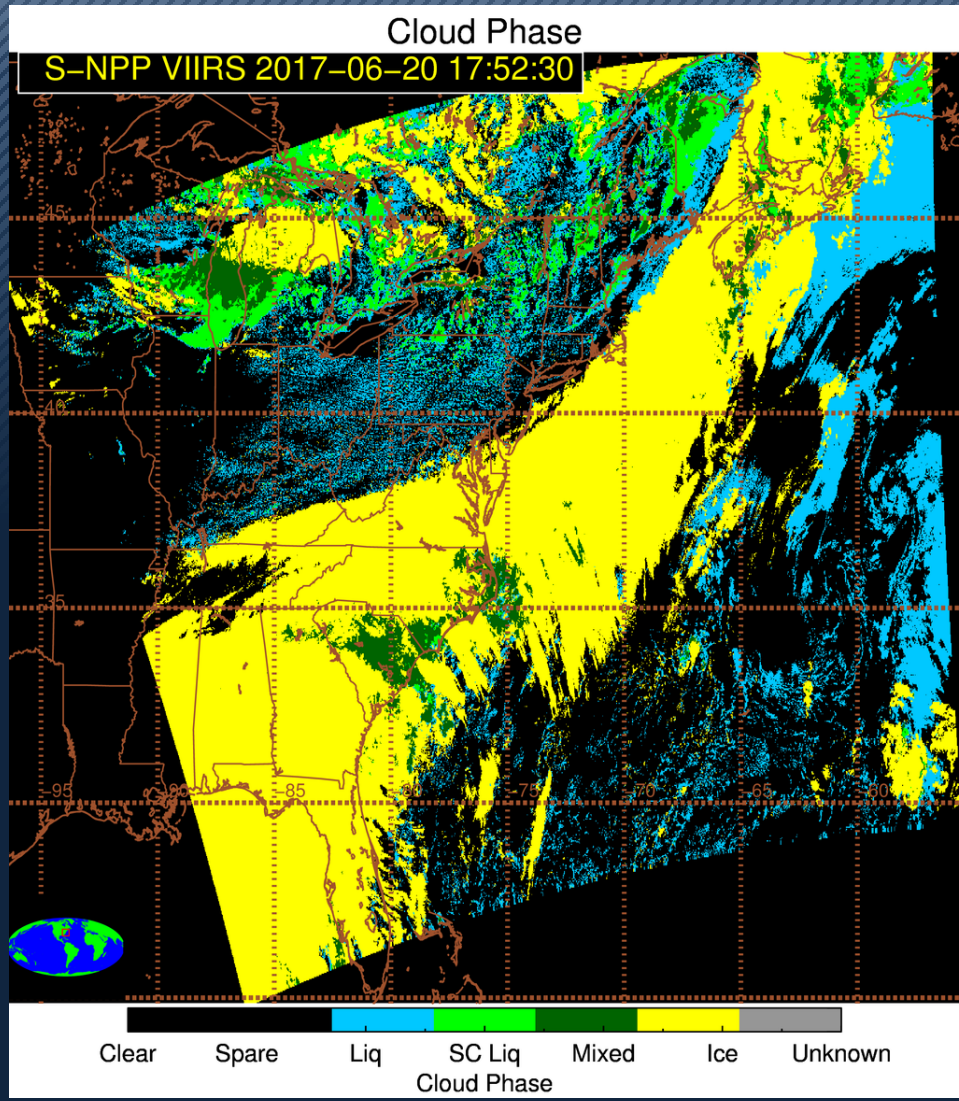


VIIRS NDE vs GOES-16 ABI from GS

False Color Imagery



VIIRS NDE Cloud Phase



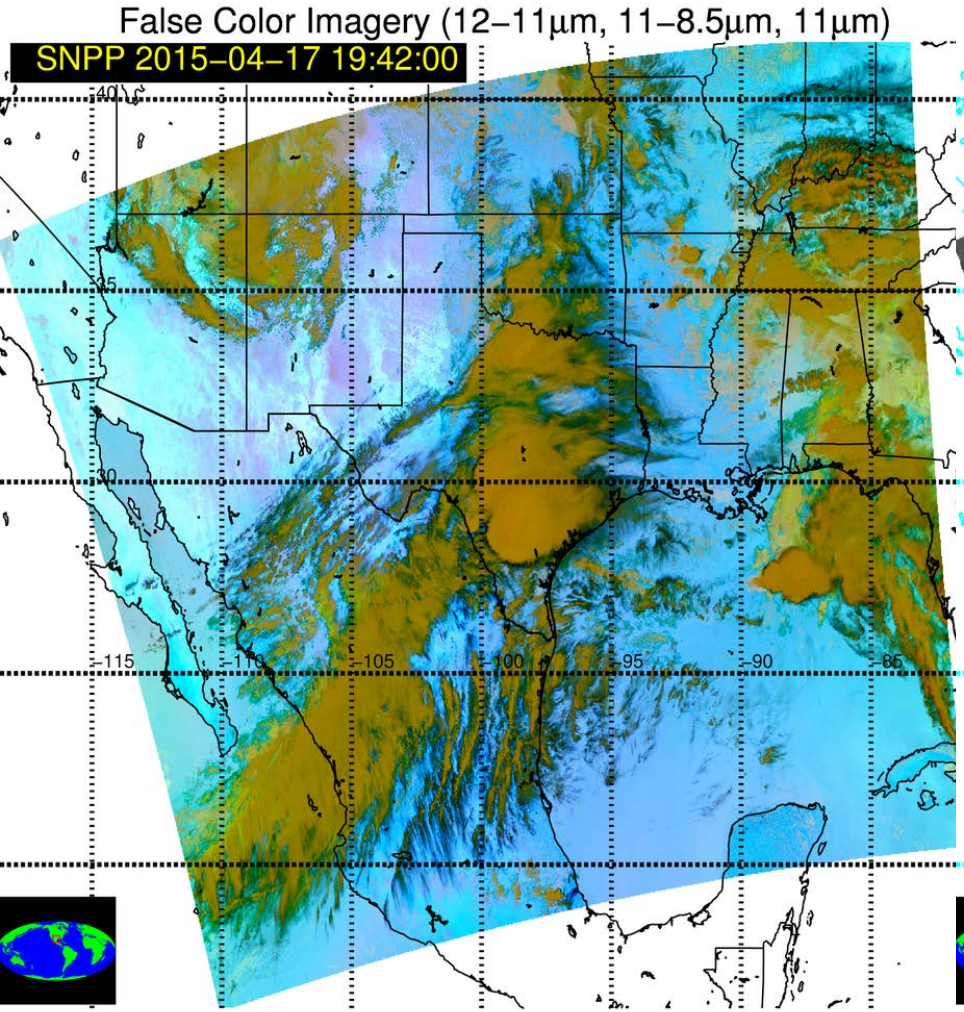
VIIRS NDE vs GOES-16 ABI from GS

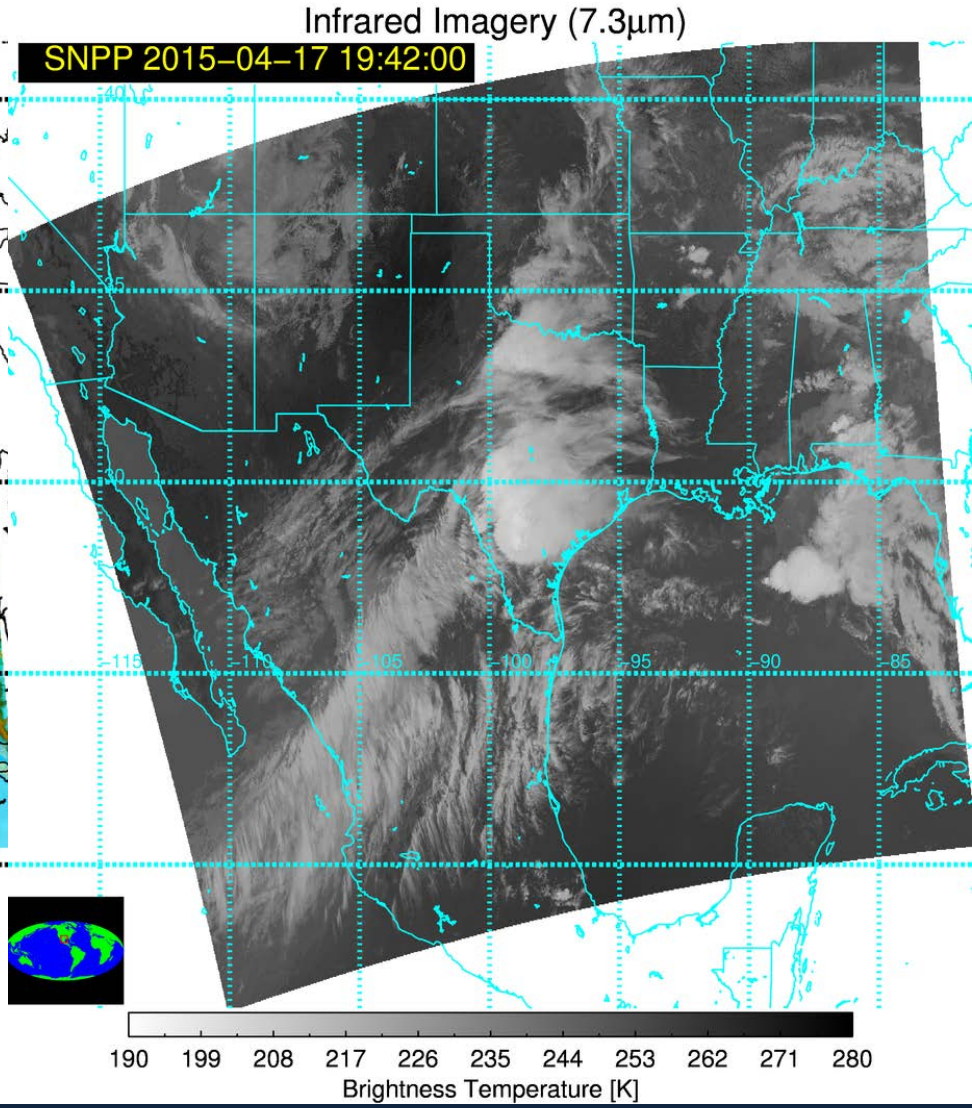
VIIRS \ ABI	Liquid	Supercooled	Mixed	Ice	Total
Liquid	924996 (17.20%)	43766 (0.81%)	12167 (0.23%)	141531 (2.63%)	1122460 (20.87%)
Supercooled	74126 (1.38%)	187852 (3.49%)	33211 (0.62%)	50590 (0.94%)	345779 (6.43%)
Mixed	18056 (0.34%)	41011 (0.76%)	100420 (1.87%)	236750 (4.40%)	396237 (7.37%)
Ice	117529 (2.19%)	15822 (0.29%)	35629 (0.66%)	3344144 (62.19%)	3513124 (65.33%)
Total	1134707 (21.10%)	288451 (5.36%)	181427 (3.37%)	3773015 (70.17%)	5377600 (100%)

The GOES-16 ABI product detects about 5% more ice clouds. Most are thin cirrus that are difficult to detect without infrared absorption channels, which VIIRS lacks.

Planned Improvements

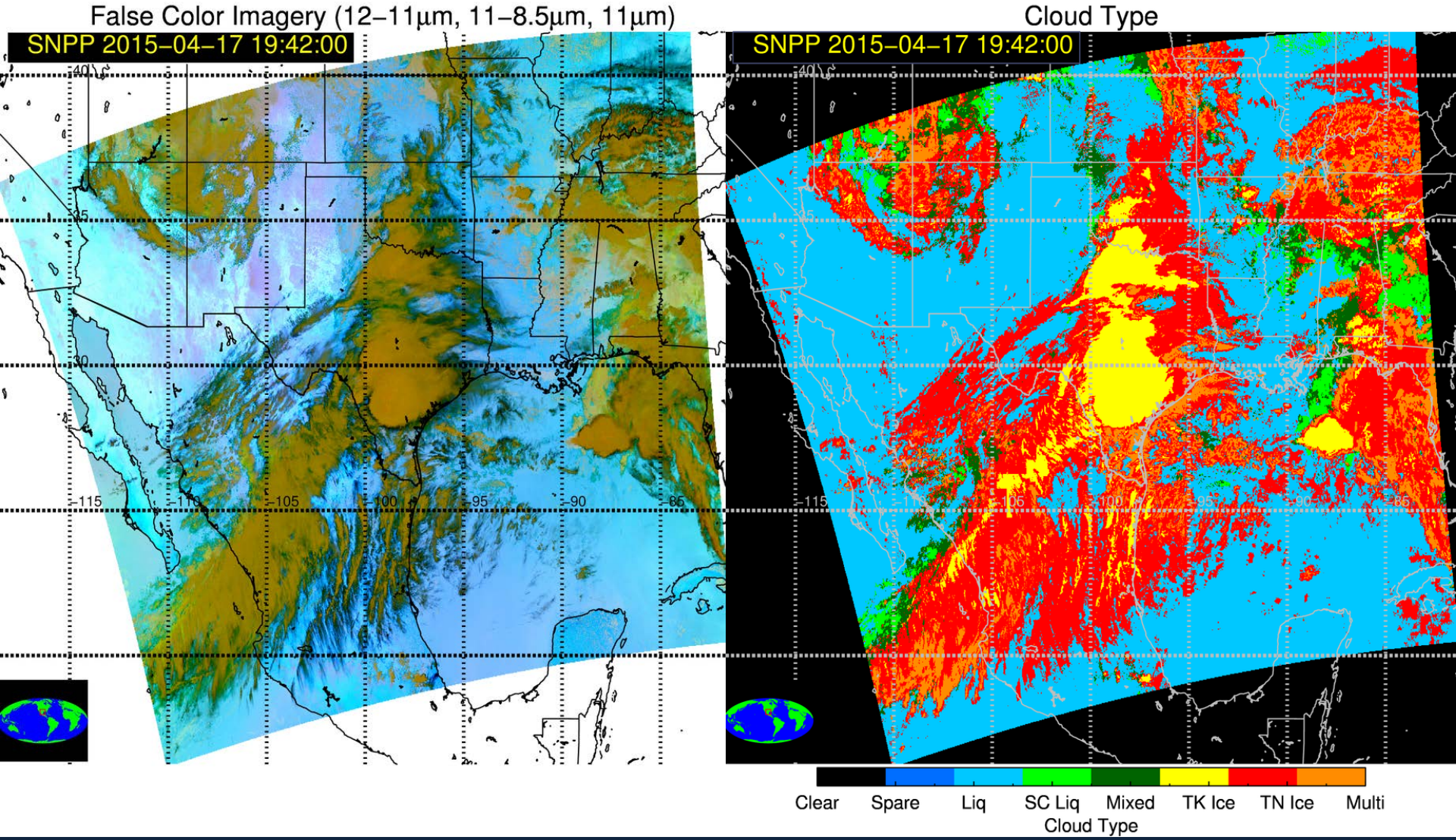
7.3 µm pseudo-channel





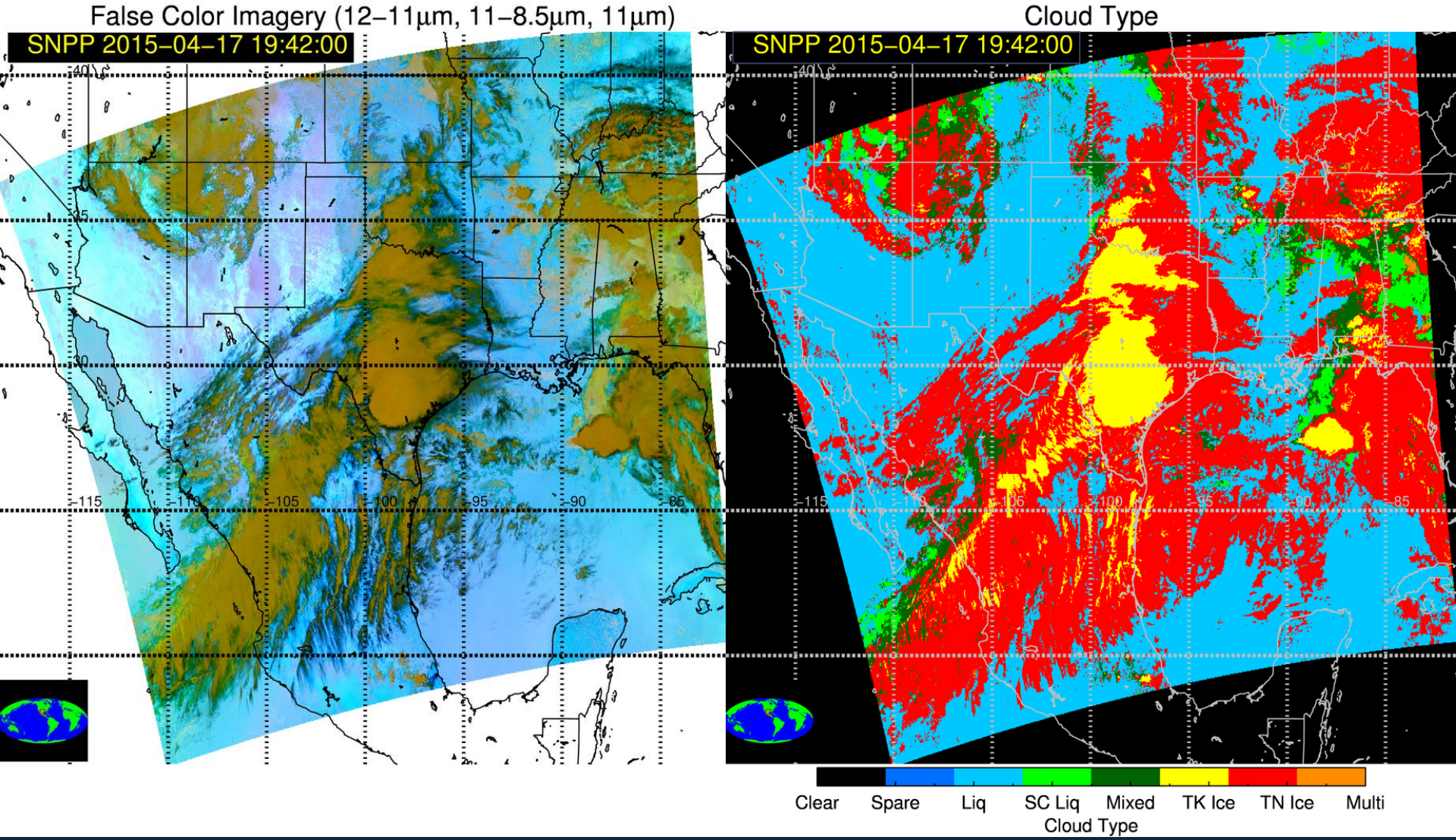
Planned Improvements

With 7.3 µm pseudo-channel



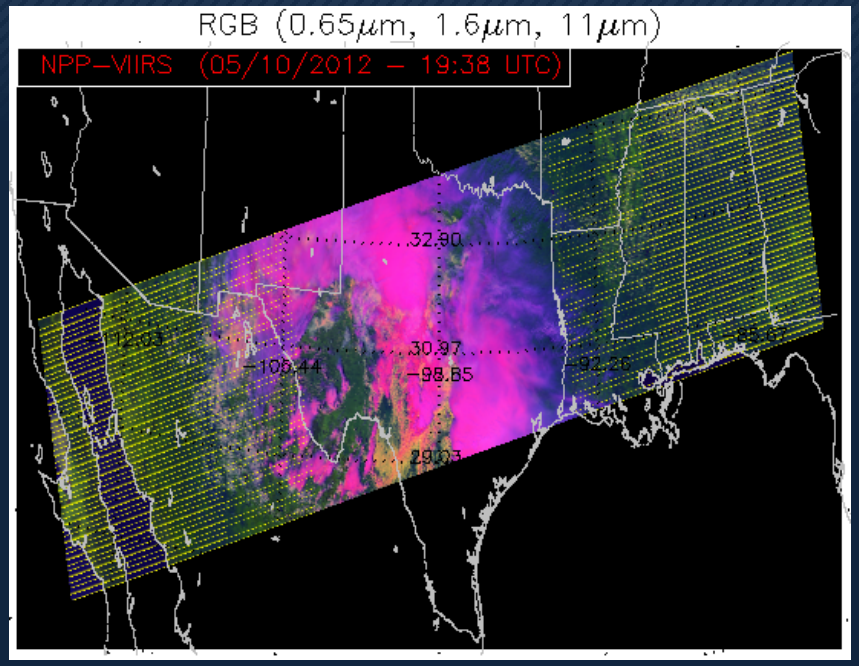
Planned Improvements

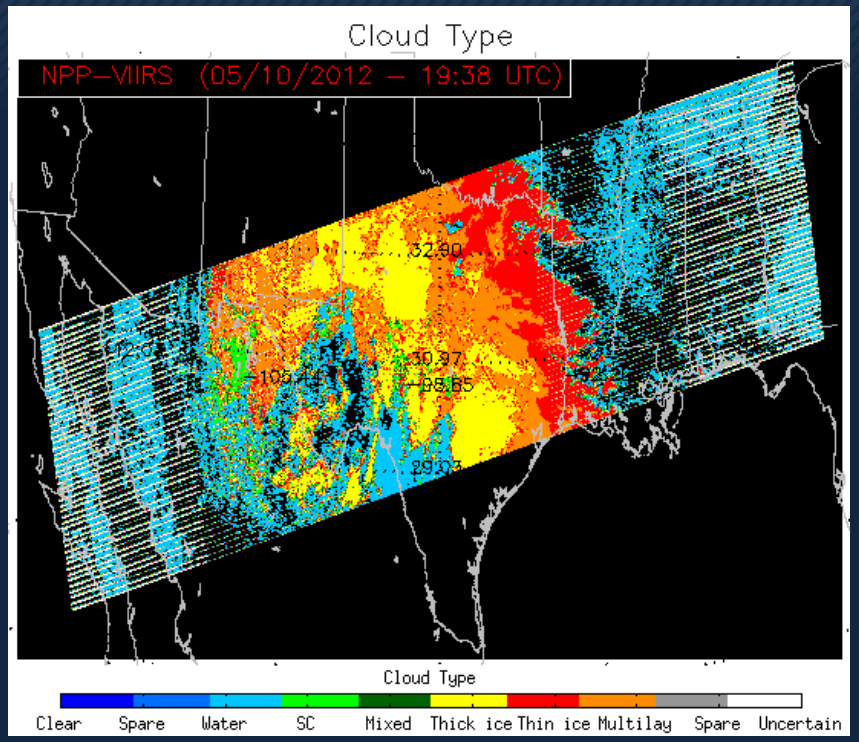
Without 7.3 µm pseudo-channel



Future Plans

- **Optimize thresholds for on-orbit JPSS-1 data**
- **Continue to explore use of CrIS measurements, including pseudo-channels**
- **Integration of near-infrared measurements (produce IR-only and IR + NIR products?)**





VIIRS CLOUD OPTICAL AND MICROPHYSICAL PROPERTIES AND THEIR APPLICATIONS

Andi Walther[1], Andrew Heidinger[2]

1 SSEC, University of Wisconsin, Madison

2 NOAA/NESDIS/STAR, Madison

Overview:
Cloud optical properties and techniques

- Products are Clouds Cloud optical thickness (COD or τ), cloud effective particle size (REF or r_e) and ice and liquid water path (IWP,LWP)

  - Using reflectance measurements in solar spectrum (0.6μm or 0.8μm for COD , and 1.6μm, 2.1μm, 3.7μm bands for r_e) from backscattered sun light during daylight

  - IR imager and sounder retrievals of COD and r_e for thin cirrus clouds

  - Microwave radiometers for water path

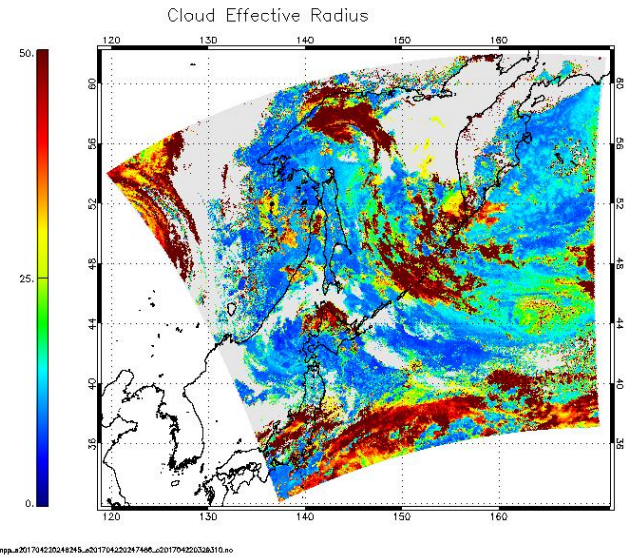
  - Using reflectance measurements in solar spectrum (DNB broad band for COD , and 3.7μm band for r_e) from backscattered moon light during night.

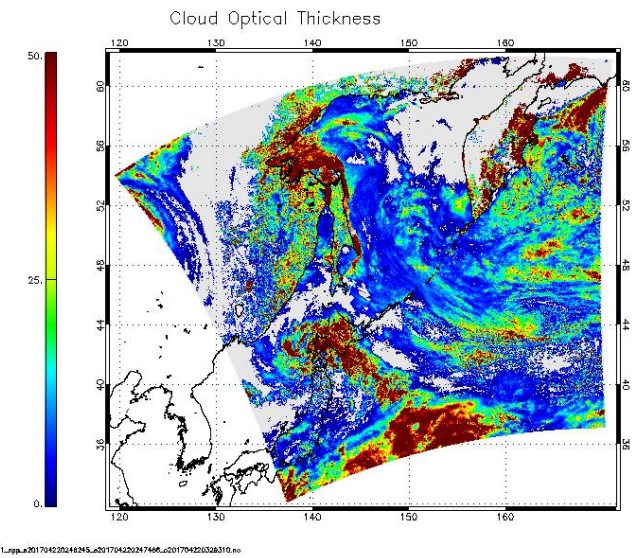
  - Water path are directly computed from COD and REF under adiabatic assumption.

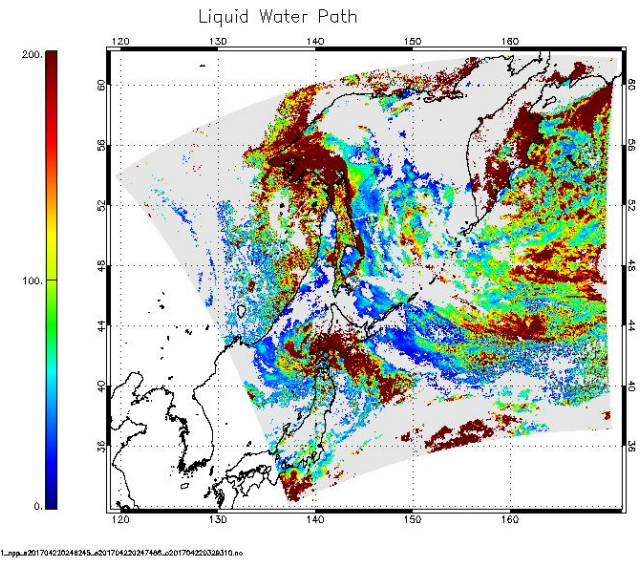
Status of Daytime Cloud Optical and Microphysical Products (DCOMP) retrieval components

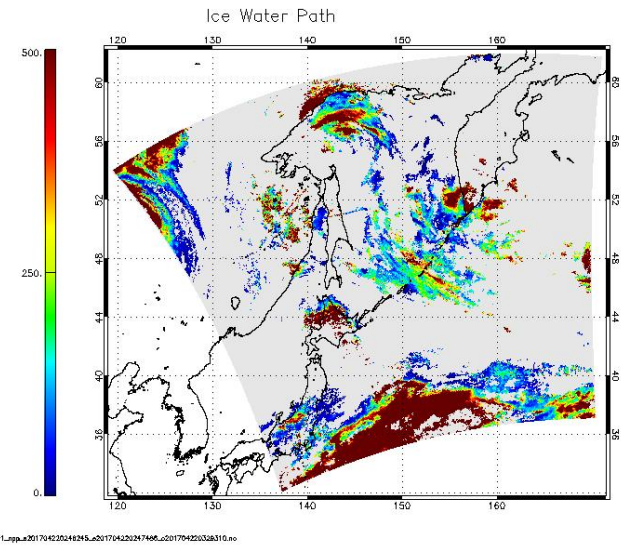
- Scientific data products are COD, REF, LWP and IWP
- Several DCOMP channel configurations possible: 1 (Channels M5/M10) ; **2 (M5/M11);** 3 (M5/M12)
- Cloud mask: Use of VIIRS Bayesian cloud mask, only use cloudy or likely cloudy pixels
- Cloud thermodynamic phase at cloud top (ice or liquid): Use of VIIRs cloud phase algorithm
- One-layer cloud assumption
- Surface spectral albedo: Include ancillary data (MODIS-based multiple year climatology)
- Use of CSFR ancillary data for snow and sea ice extent
- Atmospheric correction: requires CSFR or GFS ancillary information of water vapor and temperature profile and cloud top pressure from ACHA cloud retrieval.
- Optimal estimation inversion technique provides physically-based product uncertainty.
- Large parts of forward model are precomputed and stored in LUTs.
- Ice clouds phase functions: Use of habit “aggregate column” database by Yang and Baum
- Modular design of DCOMP. Identical software runs for all current sensors

Assessment of current operational data (SAPF)

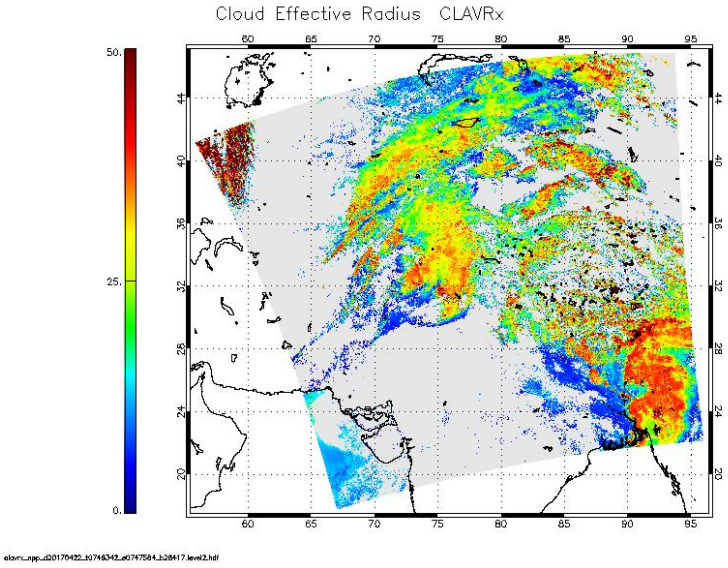


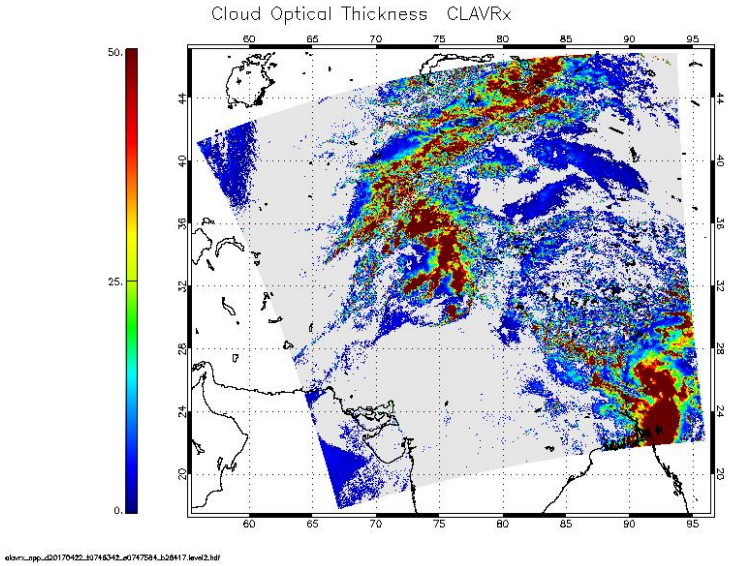




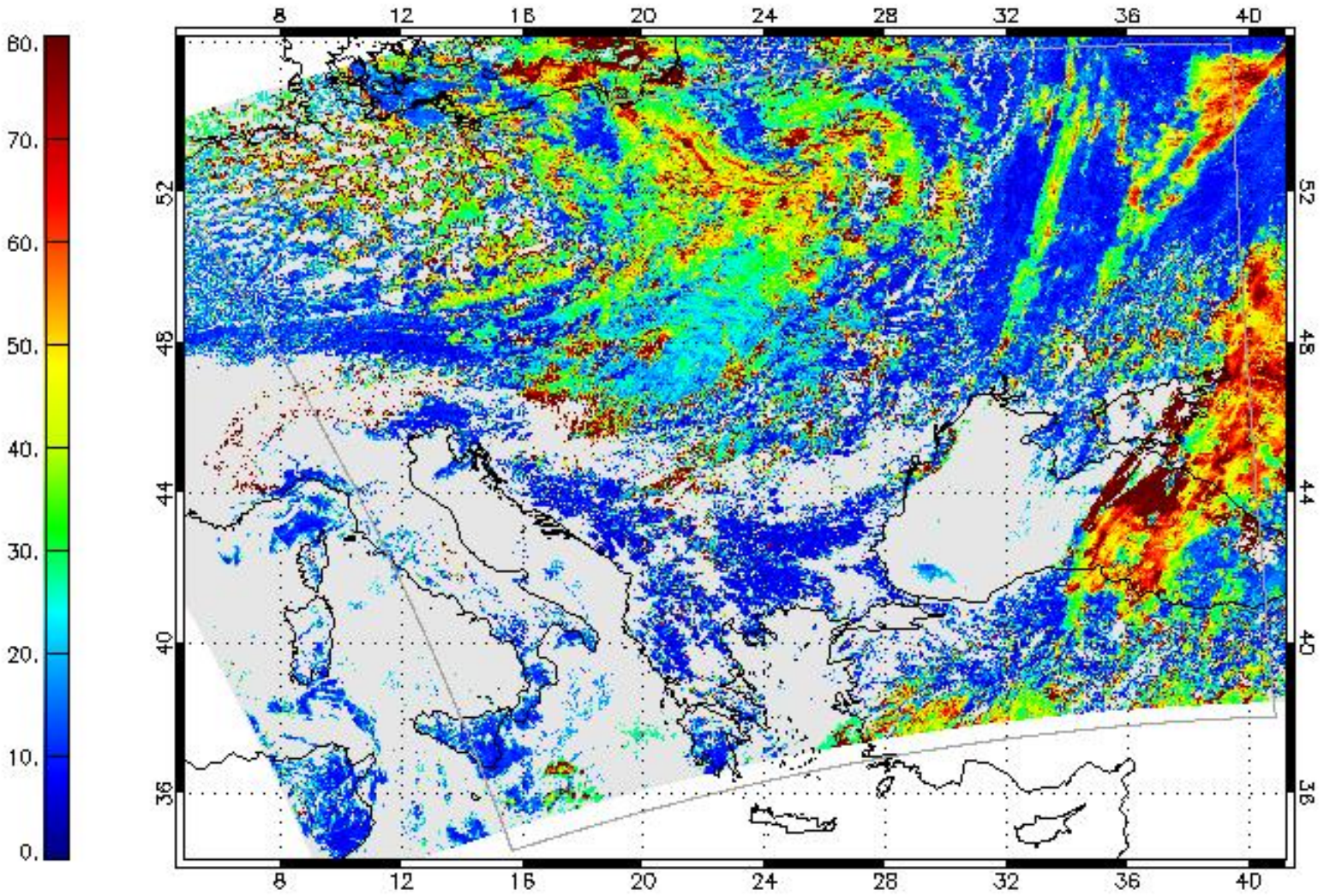


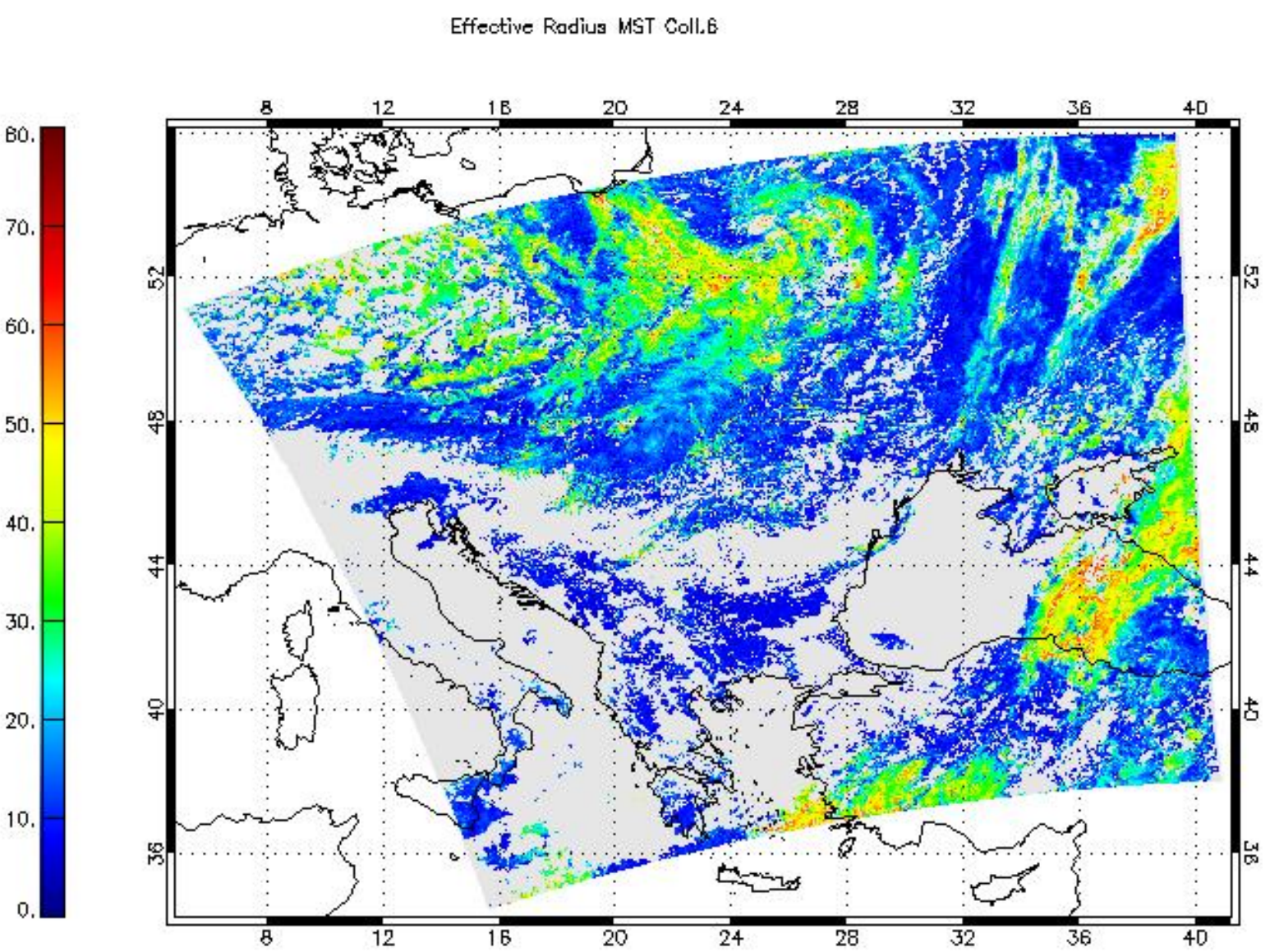
Assessment of current operational data (SAPF)



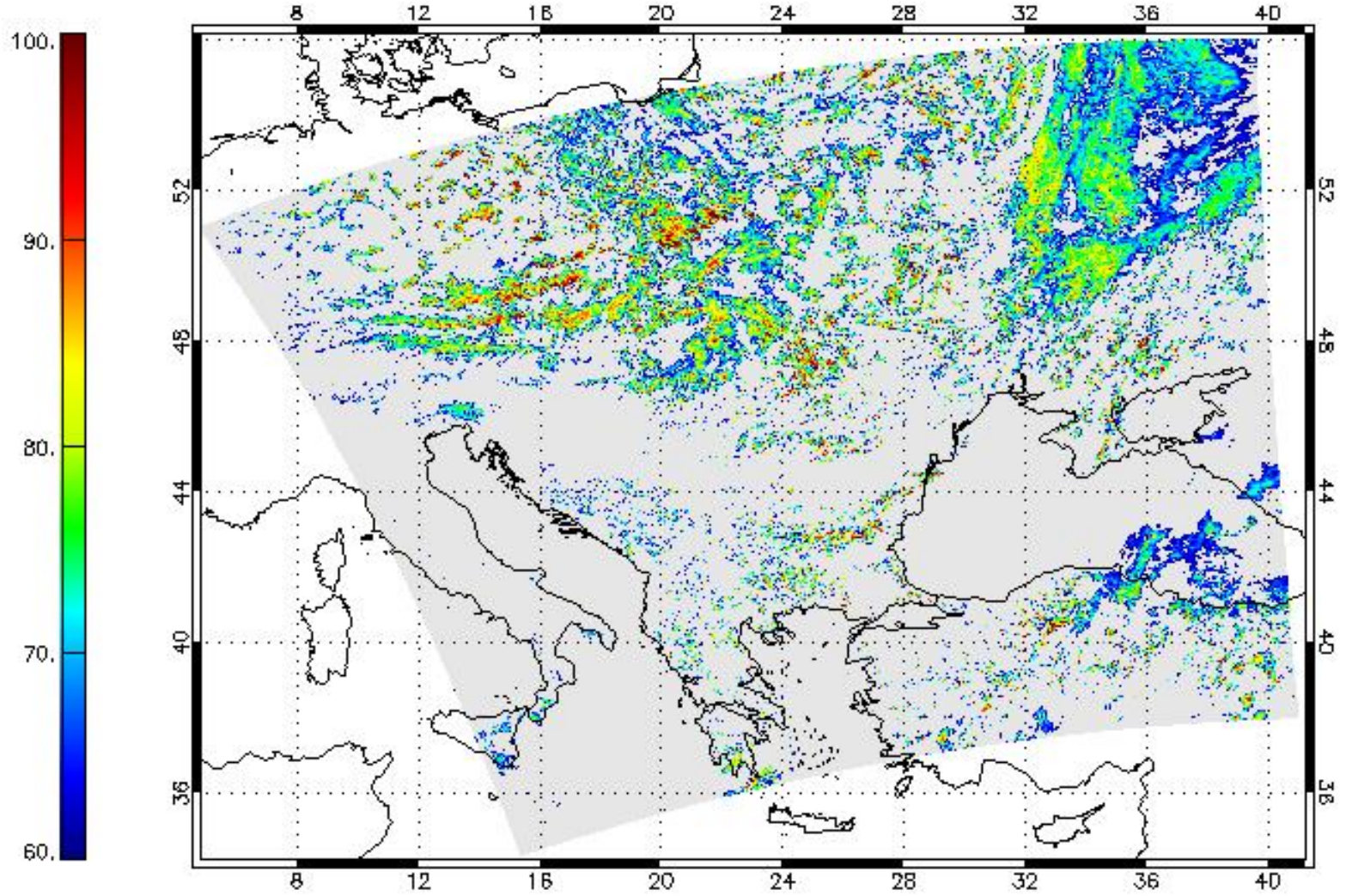


- SAPF DCOMP results show no obvious artefacts (such as “a-priori peaks” or striping etc..) on global scale.
- COD shows good agreement to current CLAVR-x version
- REF shows a bias which needs to investigate.

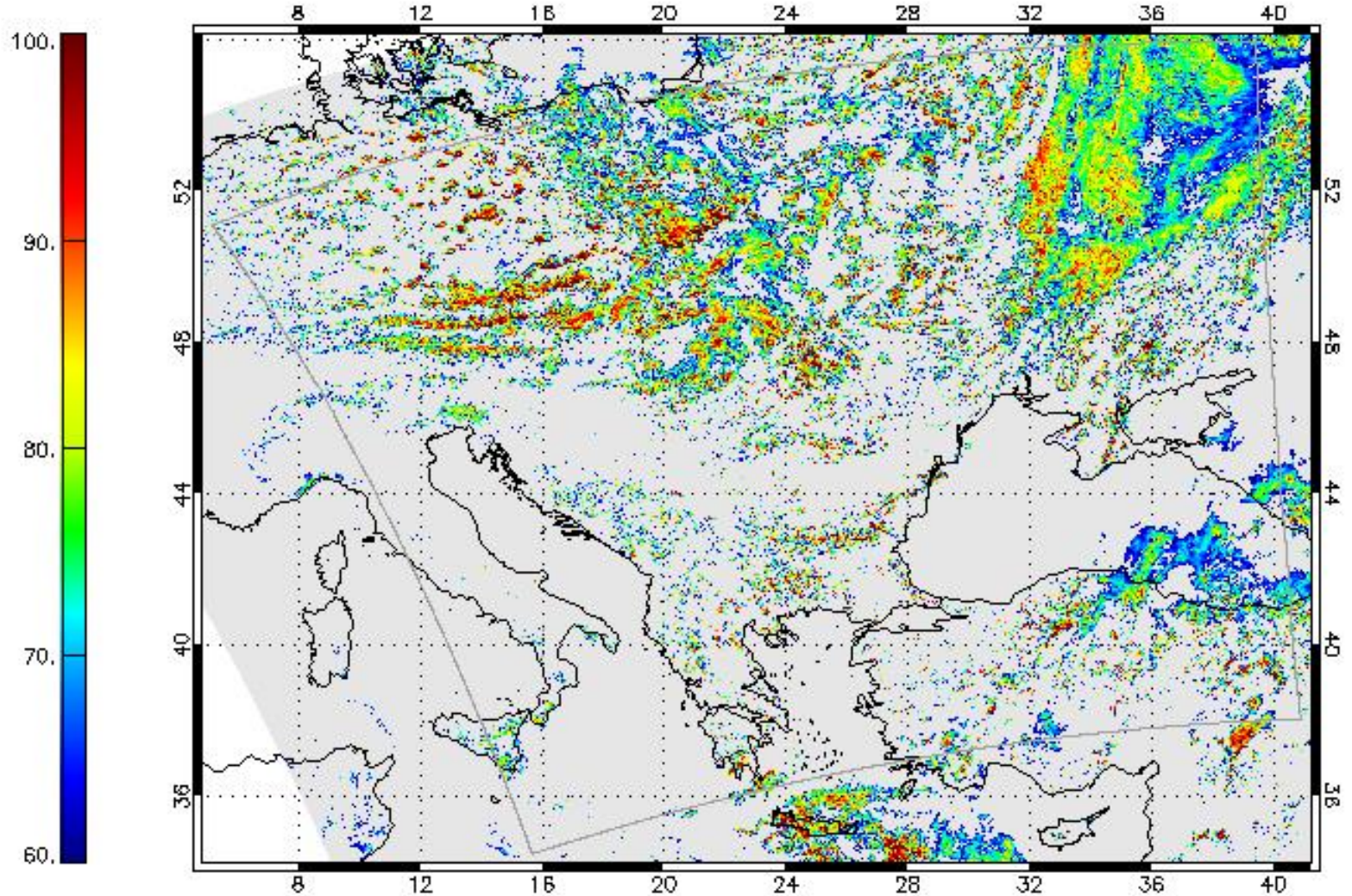

Effective Radius SAPF
80.
70.
60.
50.
40.
30.
20.
10.
0.
8
12
16
20
24
28
32
36
40
52
48
44
40
36

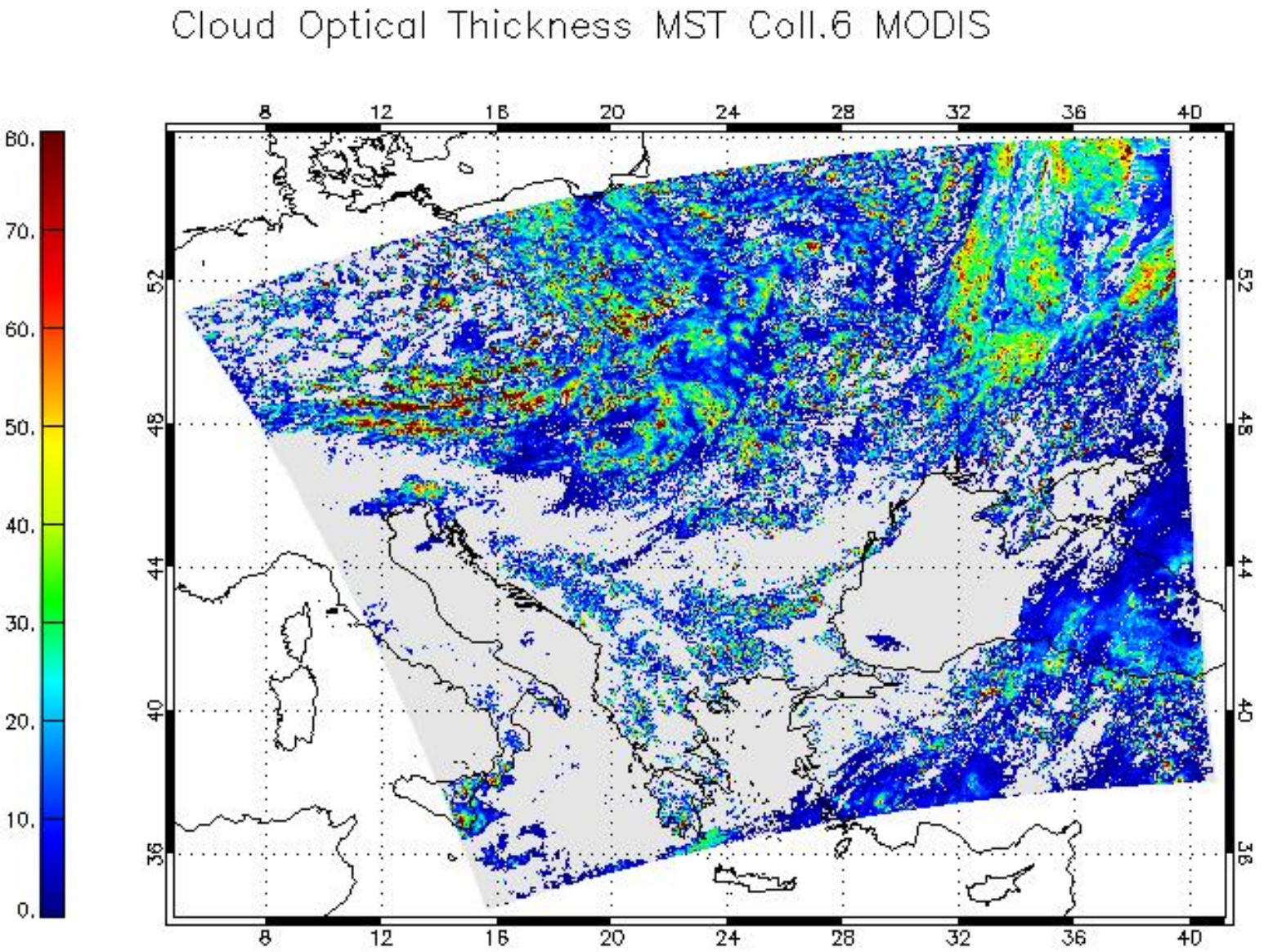

Effective Radius MST Coll.6
80.
70.
60.
50.
40.
30.
20.
10.
0.
8
12
16
20
24
28
32
36
40
52
48
44
40
36

Visible Reflectance MODIS

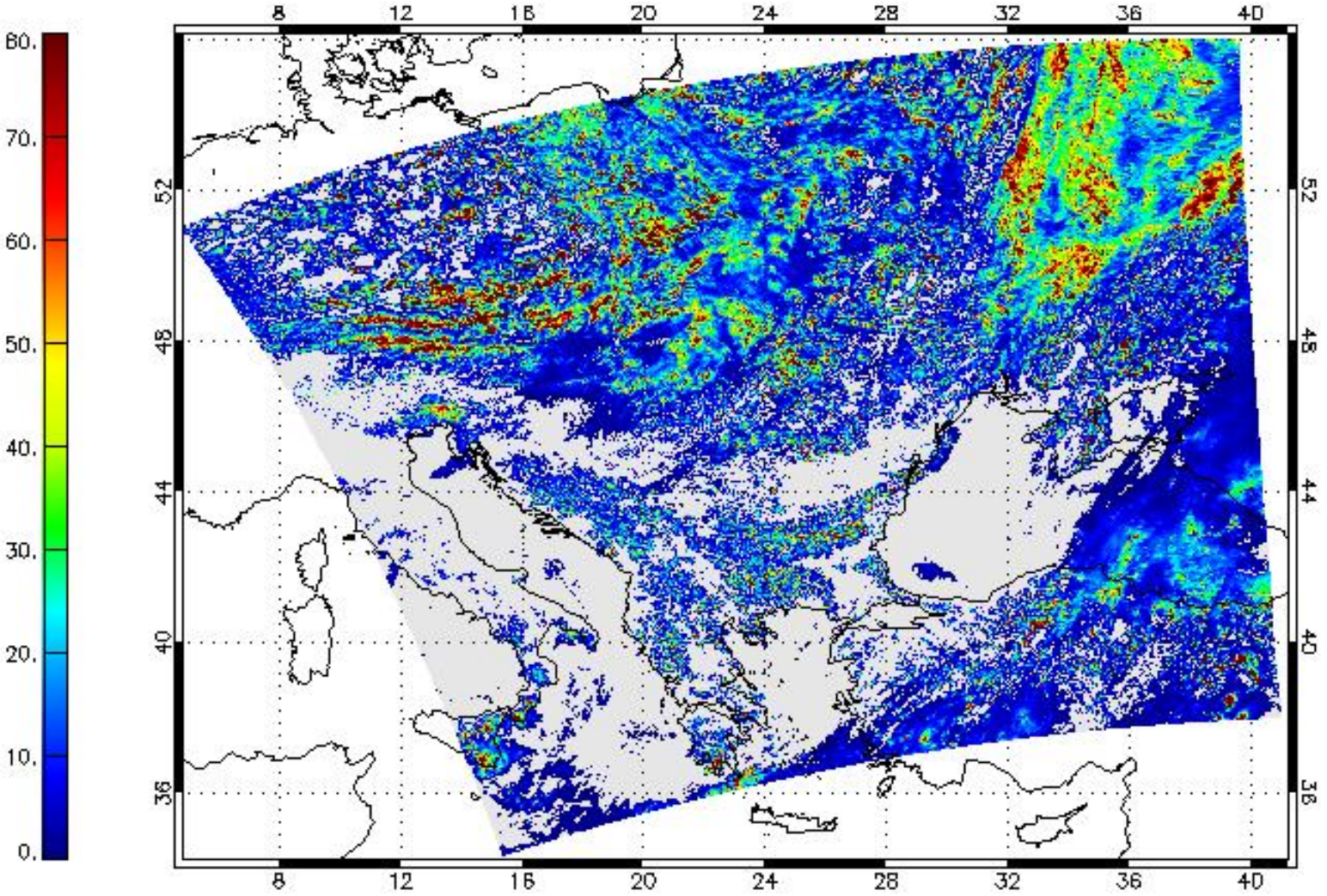


Visible Reflectance VIIRS

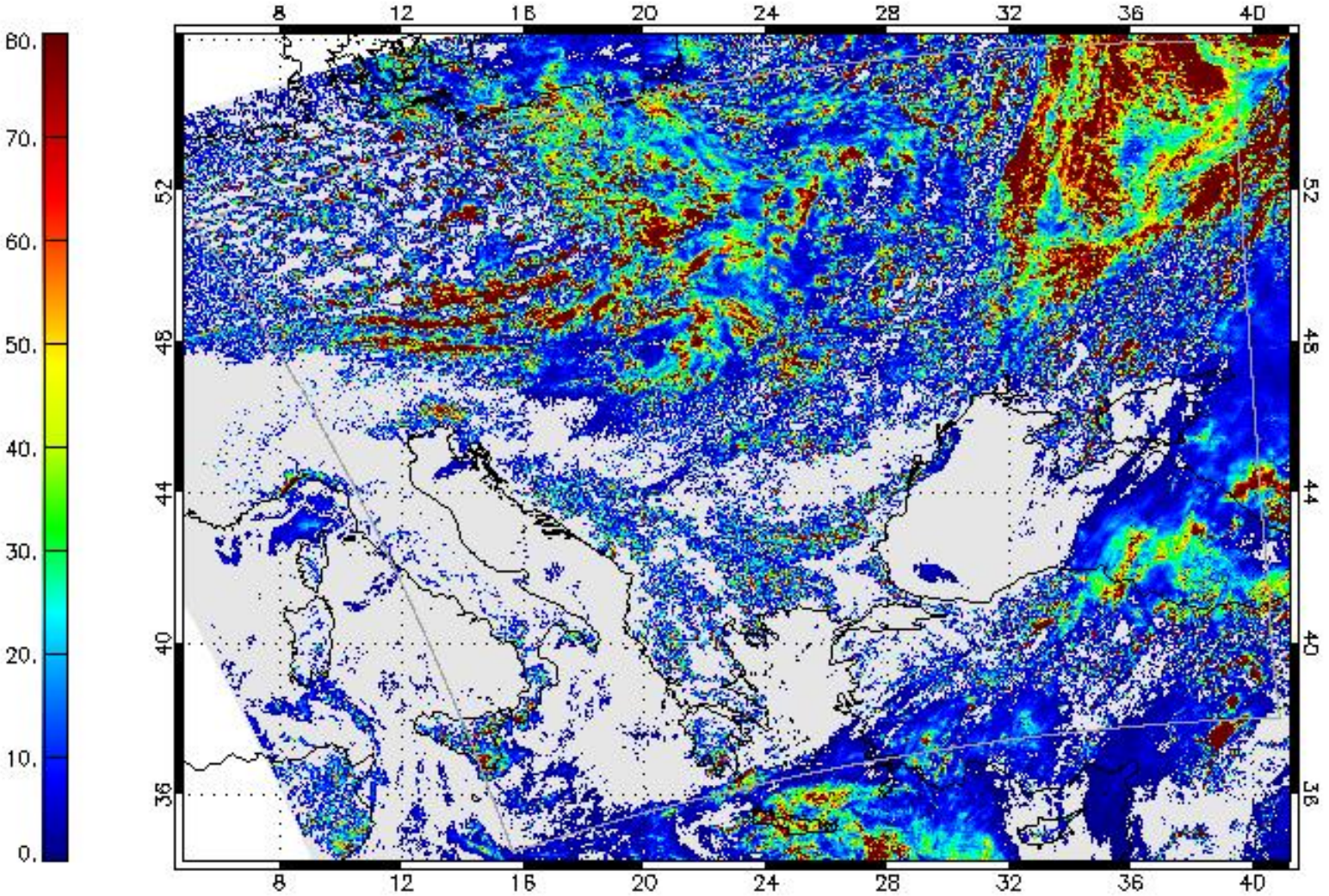



Cloud Optical Thickness MST Coll.6 MODIS
80.
70.
60.
50.
40.
30.
20.
10.
0.
8
12
16
20
24
28
32
36
40
52
48
44
40
36

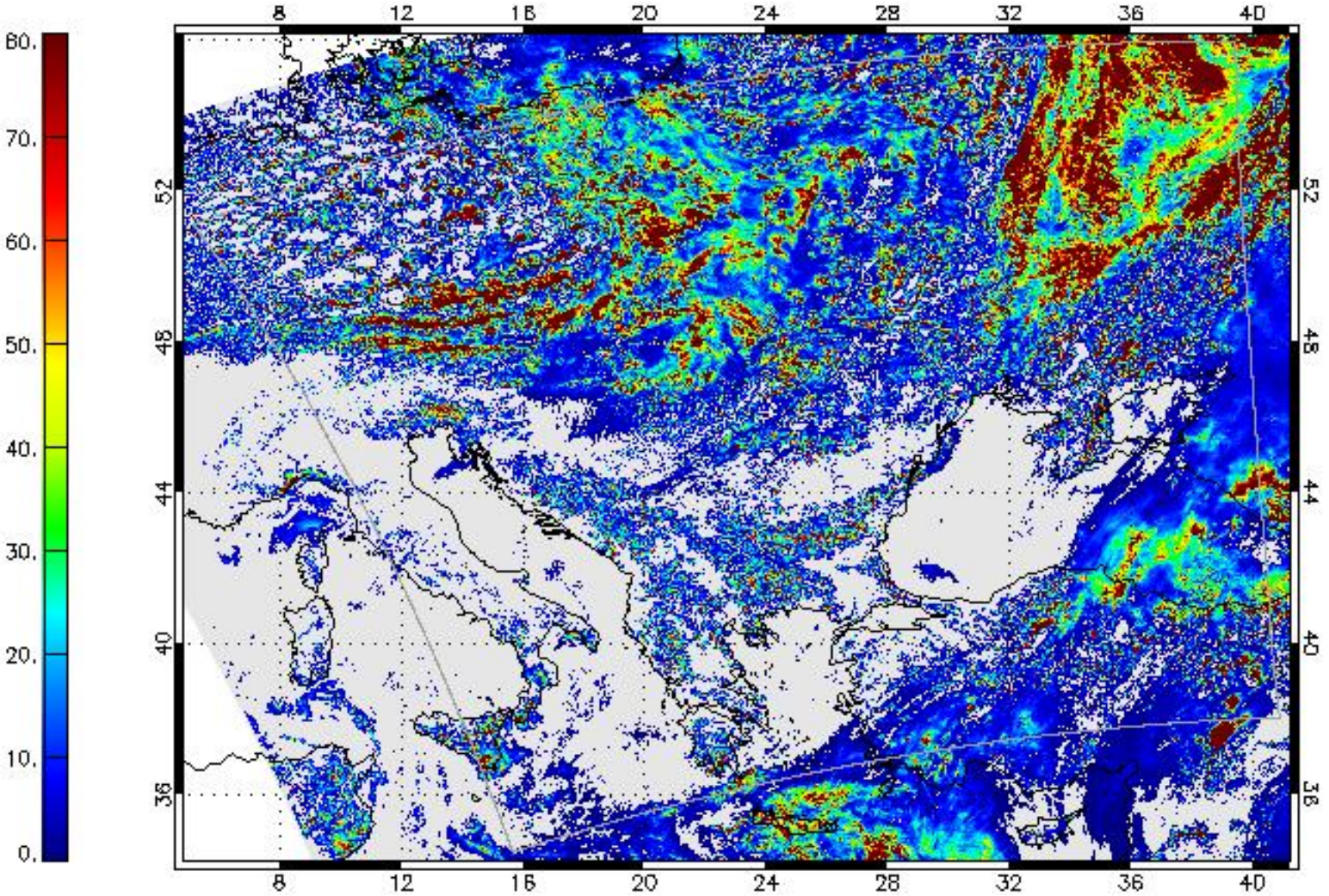
Cloud Optical Thickness CLAVR-x MODIS



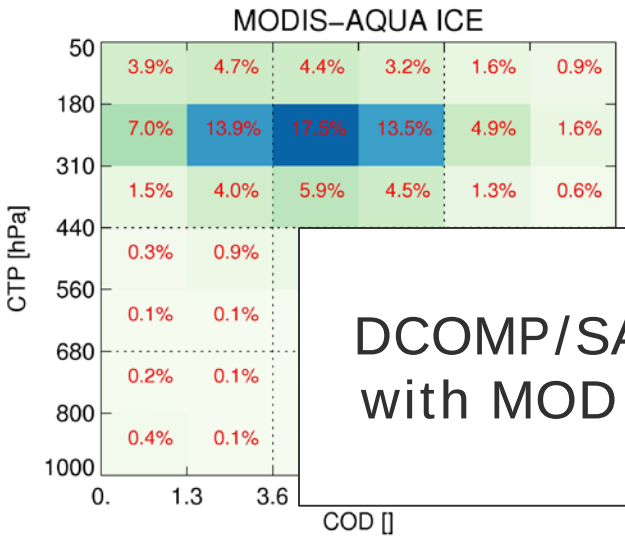
Cloud Optical Thickness CLAVR–x VIIRS

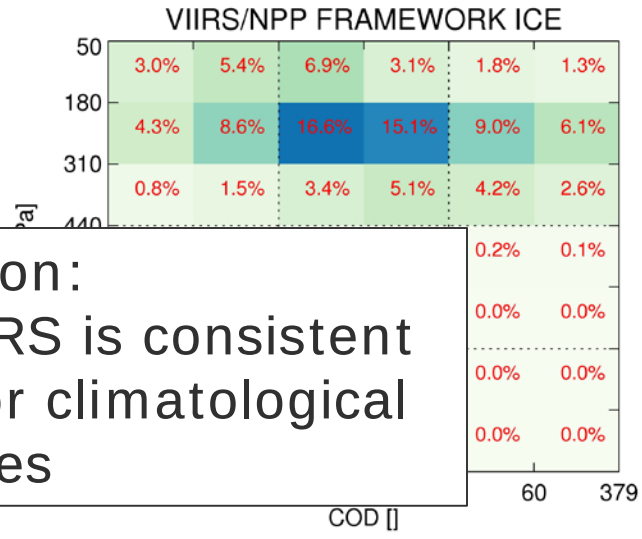


Cloud Optical Thickness SAPF VIIRS

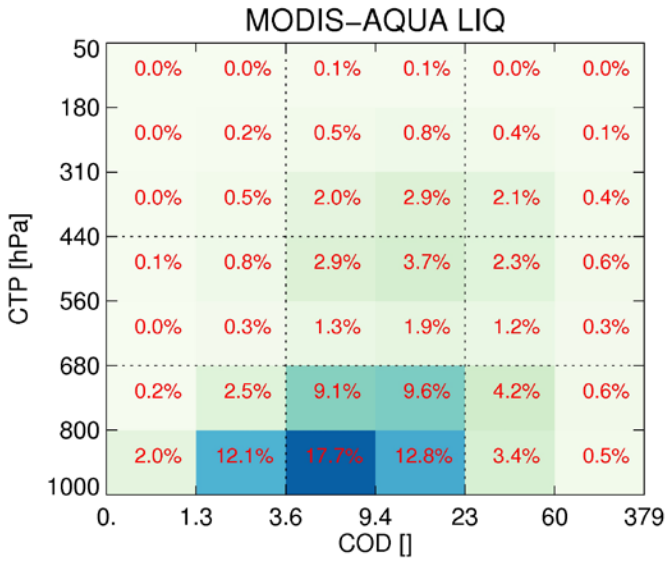


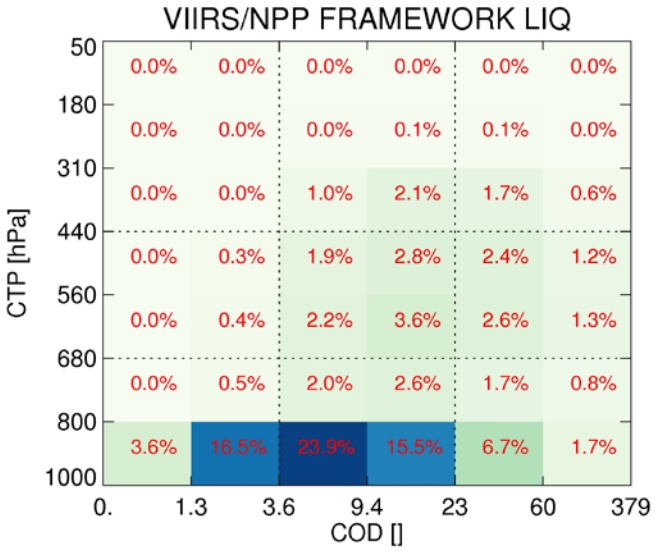
Validation results COD – MODIS: phase separated





Conclusion:
DCOMP/SAPF on VIIRS is consistent with MODIS coll.6 for climatological purposes





- **Product retrieval improvements:**
  - Use of higher resolved I-band for COD and REF at daytime
  - Near-IR only retrievals for REF over very bright surfaces (e.g. Greenland)
  - Improvements for regions and periods with highly variable snow extent
  - Optional processing of all pixel processing (no consideration of cloud mask)
  - Include Multi-layer forward model
  - Include NLCOMP, a DNB/M12-based nighttime algorithm

- **Application additions:**
  - Rain probability
  - Rain rate
  - Rain probability Night
  - Rain rate Night
  - Icing threat parameters
  - Cloud transmission

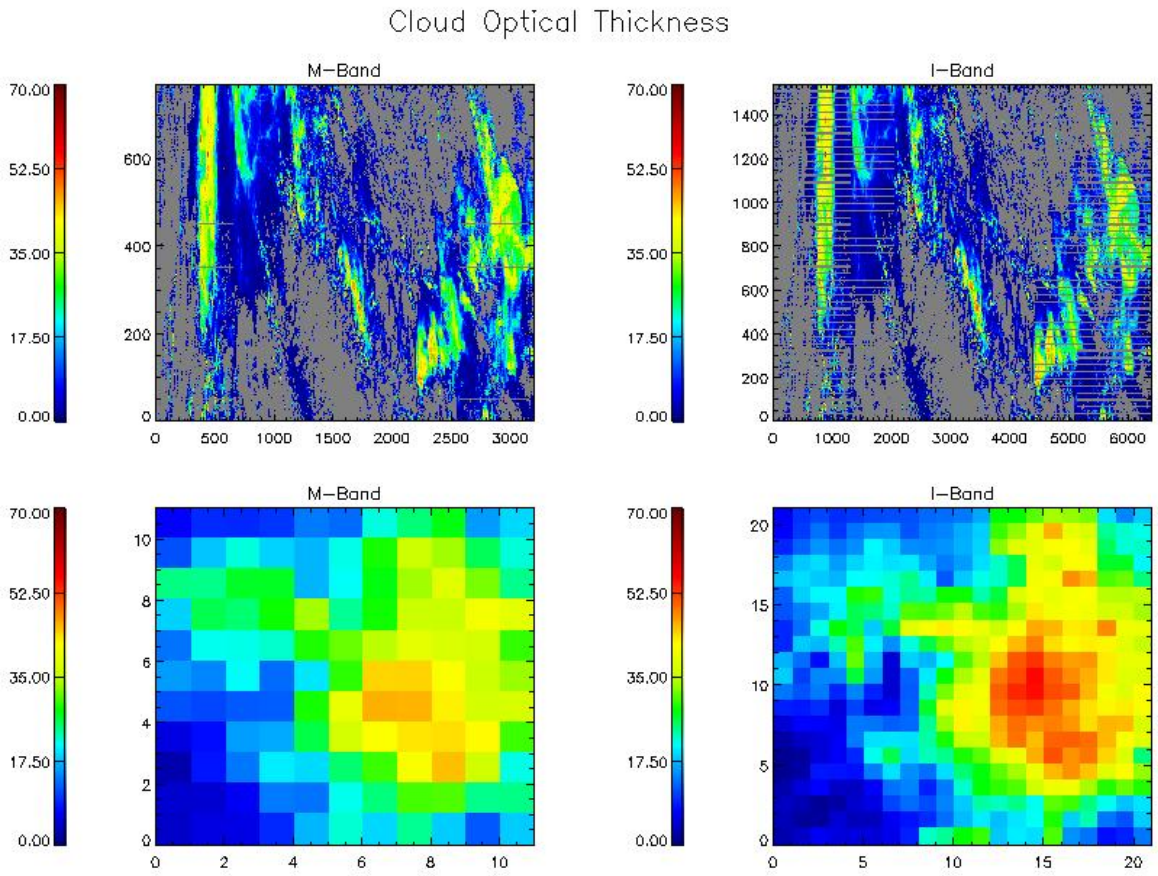
What is planned to include in future operational algorithm

- Current retrieval uses 16 M-bands (750m)
- 5 I-bands with resolution of 375m
- 4 I-band pixels are collocated with one M-band

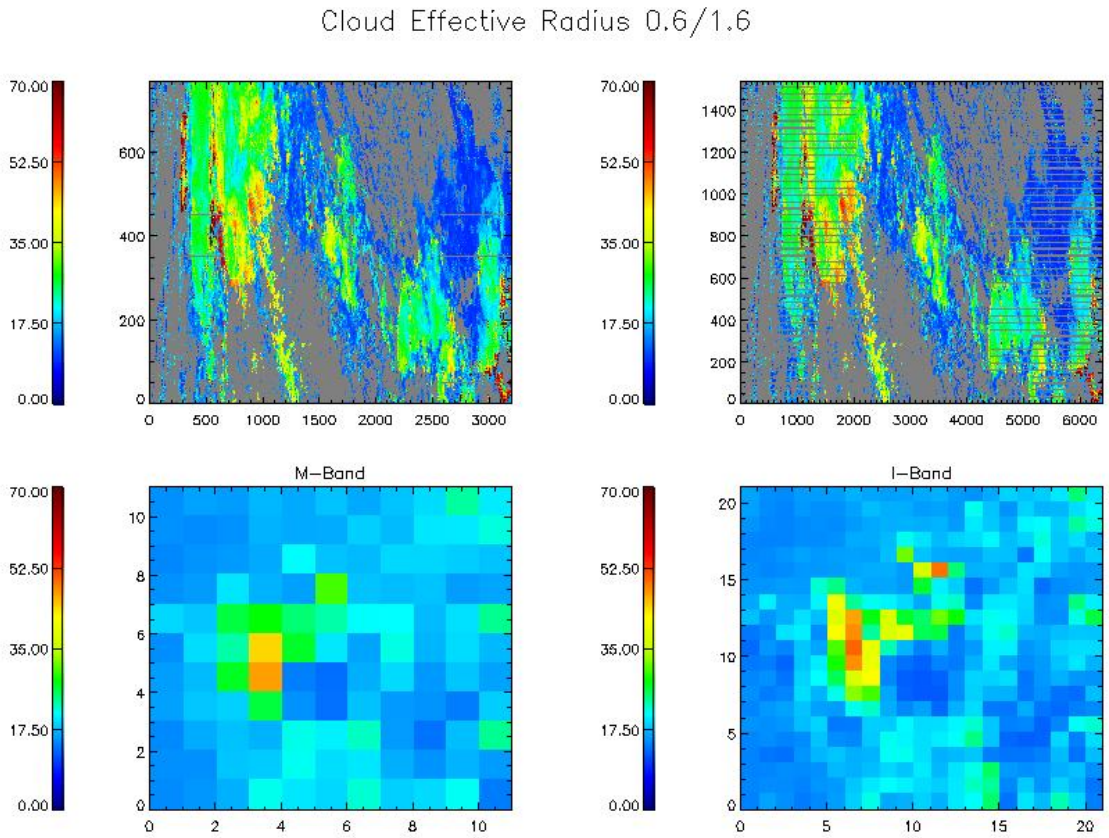
I1 (B)	0.64	0.08	0.6 - 0.68	Visible/ Reflective	375 m
I2 (G)	0.865	0.039	0.85 - 0.88	Near IR	
I3 (R)	1.61	0.06	1.58 - 1.64	Shortwave IR	
I4	3.74	0.38	3.55 - 3.93	Medium-wave IR	
I5	11.45	1.9	10.5 - 12.4	Longwave IR	

What is planned to include in future operational algorithm

- Use of higher resolved I-band for COD



- Use of higher resolved I-band for REF

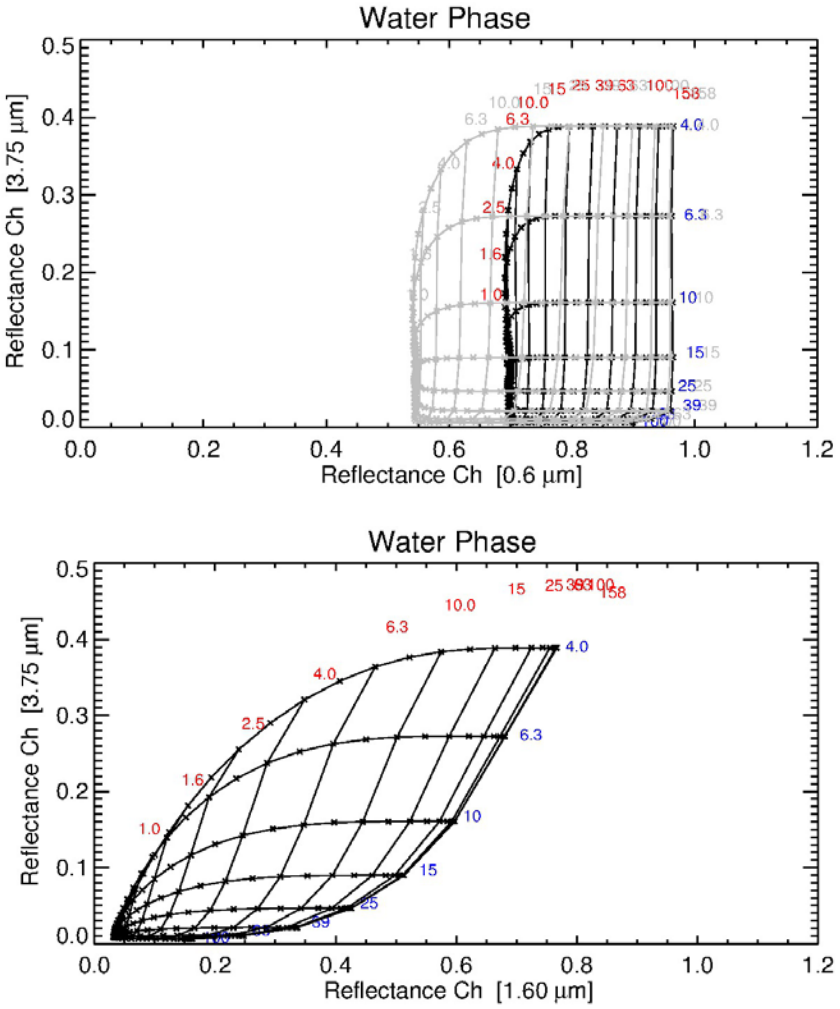


Potential benefit: better detection of small particle signatures at the genesis of severe convective storms

Retrieval over snow and sea ice:

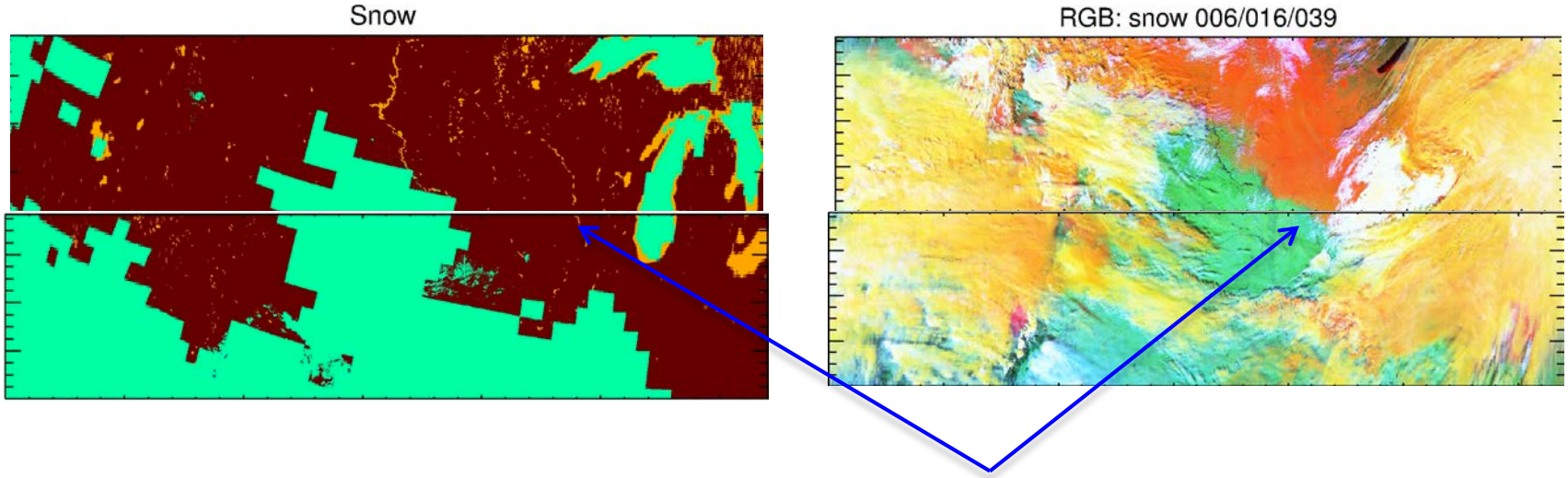
Issues in current approach:

- Snow is very bright at 0.6 and has a high surface reflectivity
- Snow reflectivity assumption is very uncertain
- COD is practically only retrievable for very thick clouds and only with very high solution uncertainty.
- Bi-spectral image suggests to use a one-channel approach for a REF-only retrieval
- Other option to include: Use of 1.6µm /3.75µm approach. (Platnick et al 2001):
  - + low snow albedo at 1.6µm
  - – low cloud reflectance
  - – less orthogonal forward model



Highly variable snow extent

- False snow/snow-free assumption causes retrieval failure for most clouds.
- Current status: CFSR NWP snow depth on 0.5/0.5 lon/lat grid 6-hourly
- Alternative option: GlobSnow Daily on 25km pixel



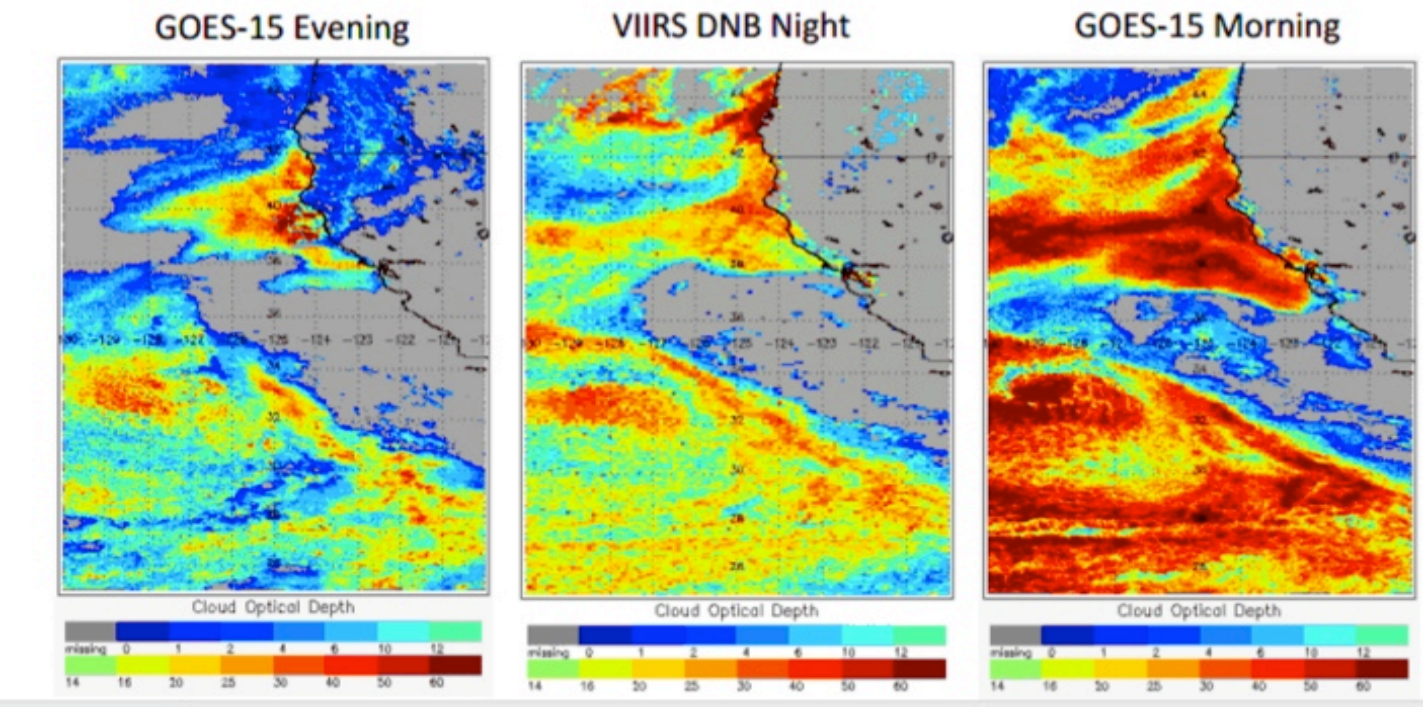
CFSR shows snow, observation snow-free

Idea for next future algorithm:

- Combining highly temporally resolved data with highly spatially resolved information
- Real-time adjustments from clear-sky pixels in neighborhood

Nighttime retrieval of COD and REF

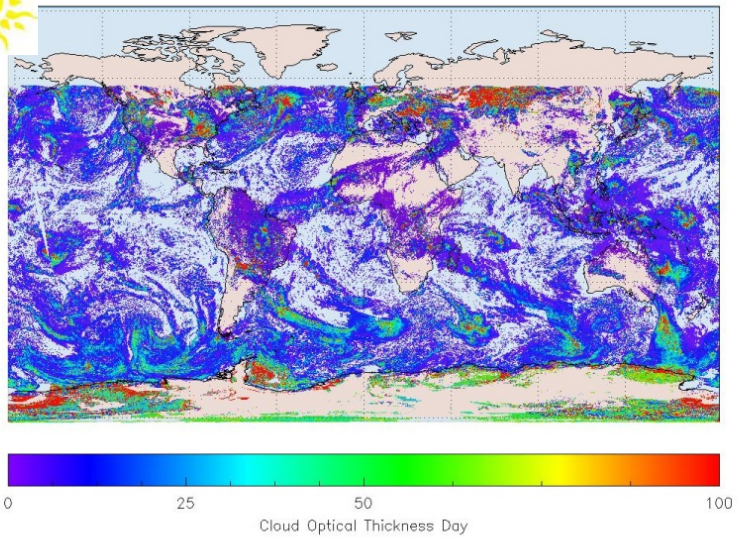
- NLCOMP (Nighttime Lunar Cloud Optical and Microphysical Properties) retrieval uses lunar irradiance calculations to derive visible reflectance in Day/Night band and use it for a DCOMP alike nighttime retrieval.

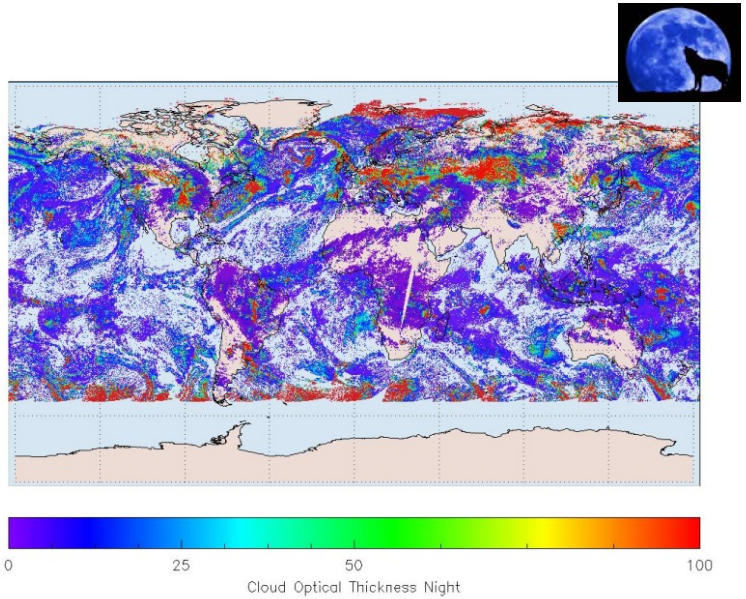


+ NLCOMP shows cloud microphysics structures also at night

Nighttime retrieval of COD and REF

- COD accuracy is slightly lower than for DCOMP due to higher uncertainty of lunar irradiance in contrast to solar irradiance
- REF accuracy is significantly lower due to missing reflectance component in NIR channel (use of emissivity forward model only)
- NLCOMP is limited to non-urban regions
- NLCOMP product coverage and accuracy is dependent on moon phase. (DNB reflectance from moon light is available at about 70% of the time but with varying accuracy)

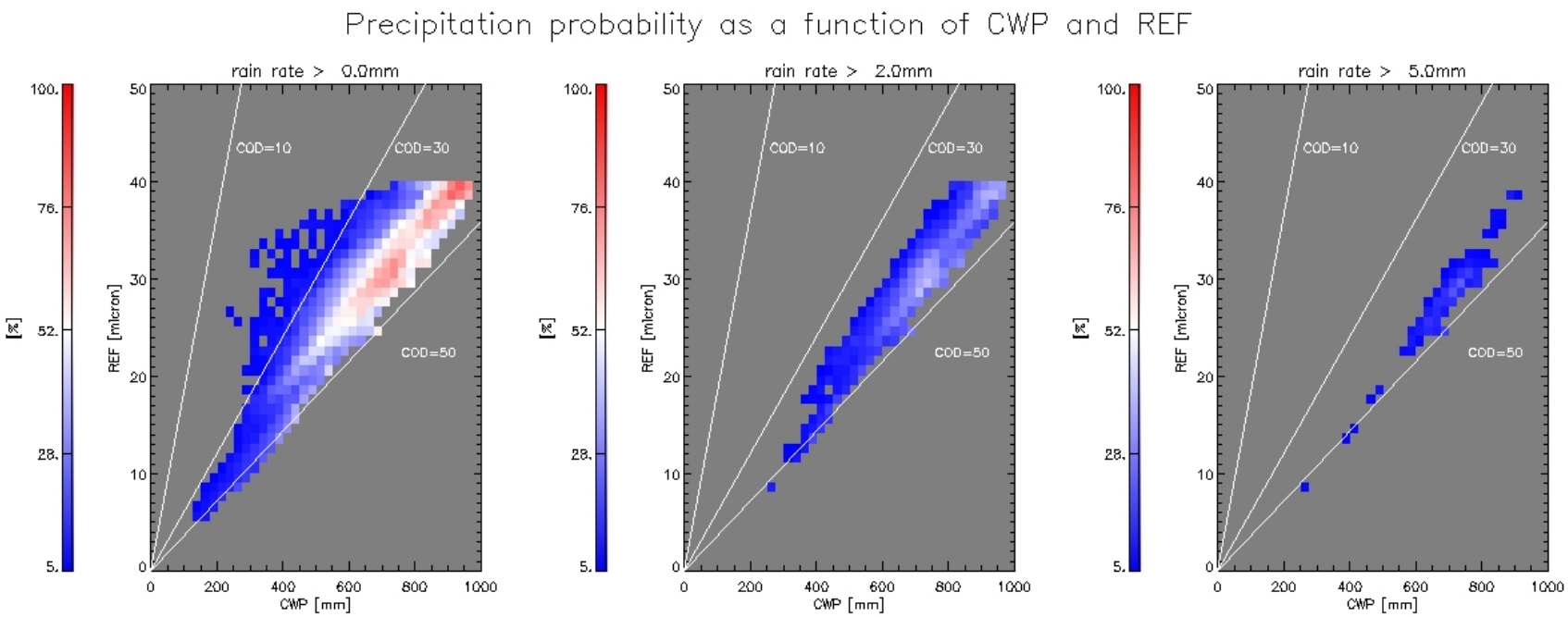




Applications: Rain probability from DCOMP products

Matching 15 days of VIIRS cloud properties with NEXRAD surface precipitation.

Images show NEXRAD precipitation above different thresholds frequency as a function of DCOMP/VIIRS cloud properties

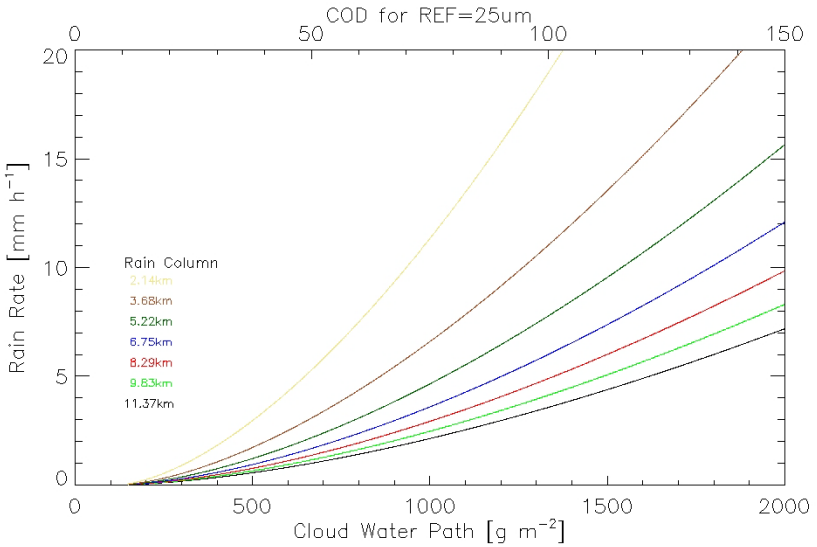


[Roebeling and Hollemann, 2011] developed a rain detection and rain rate estimate techniques which rely on cloud water path and rain column height estimated by cloud top temperature at daytime

Rain Column:

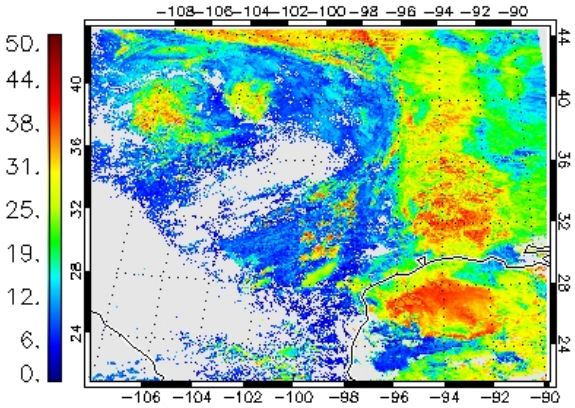
$$H = \frac{(CTT_{\max} - CTT_{pix})}{Lapse_rate} + dH$$

$$R = \frac{c}{H}\left[\frac{CWP - CWP_0}{CWP_0}\right]^{\alpha}$$

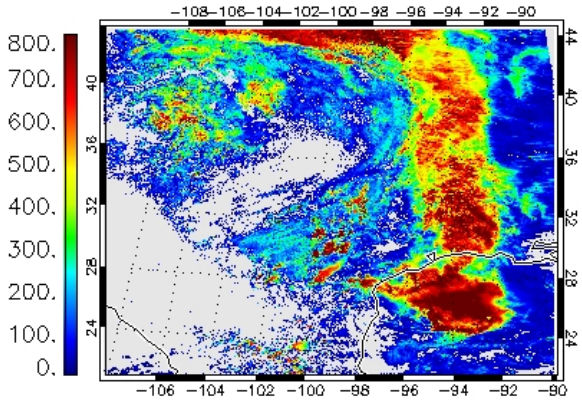


The retrieval is empirical and is based on collocated observations with ground-based measurements.

Applications: Rain rate

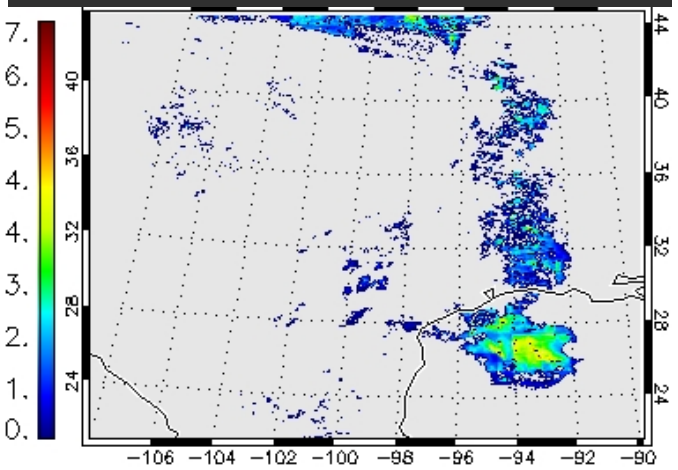


DCOMP Cloud Effective Radius



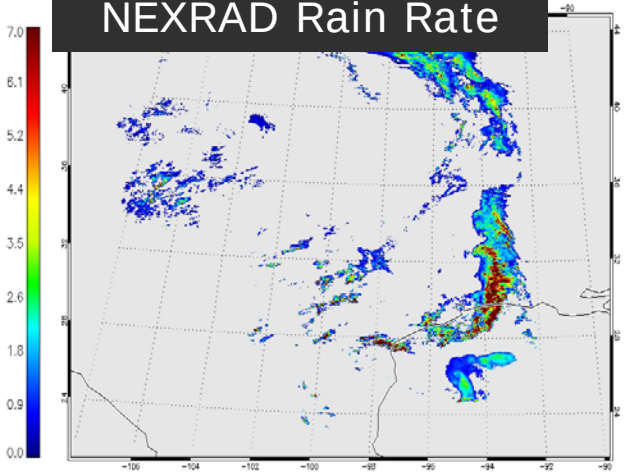
DCOMP Cloud Water Path

DCOMP Rain Rate

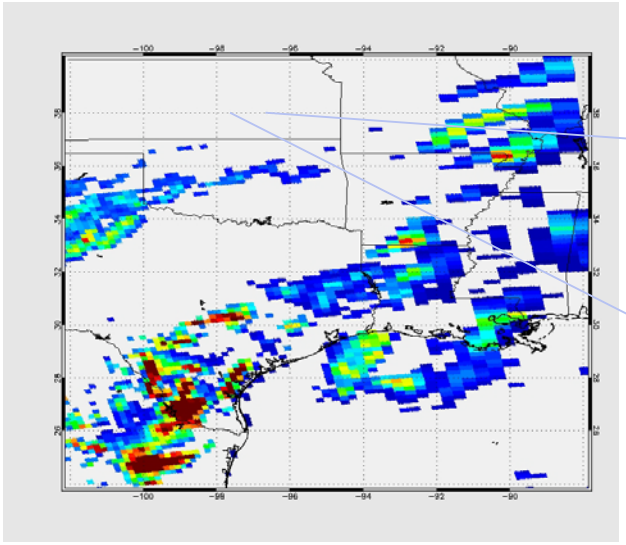


Rai rate retrieval is a DCOMP or NLCOMP based day and night retrieval
Further current developments are hybrid VIIRS/ATMS retrieval which combines the more physical-based MIRS retrieval with the empirical DCOMP retrieval

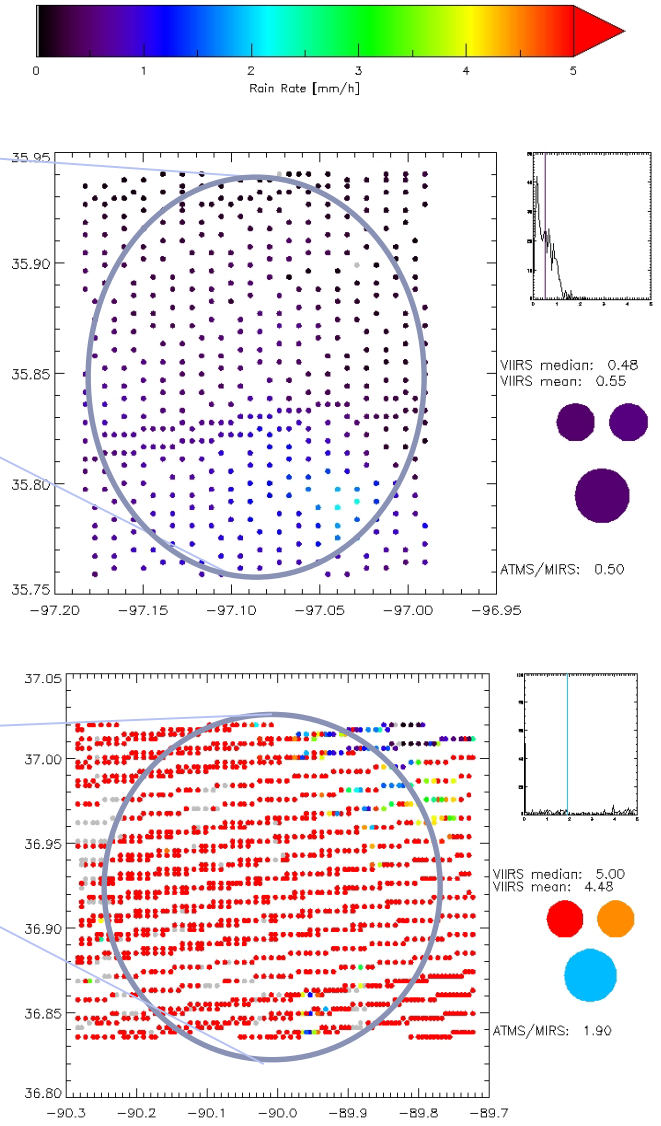
NEXRAD Rain Rate



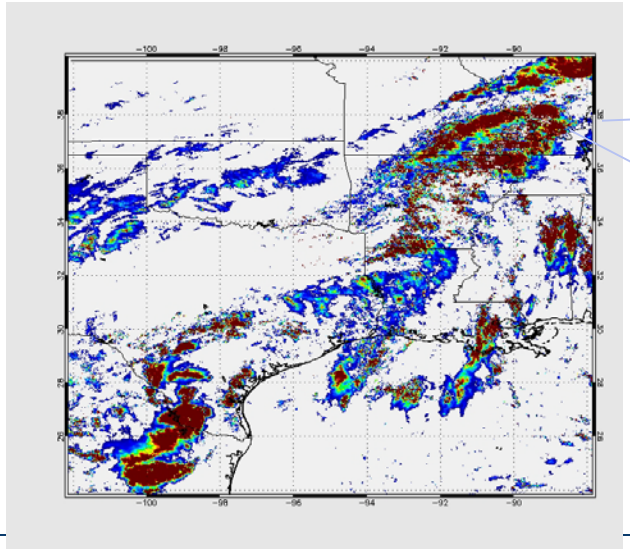
MIRS/ATMS Rain Rate



VIIRS/ATMS matching



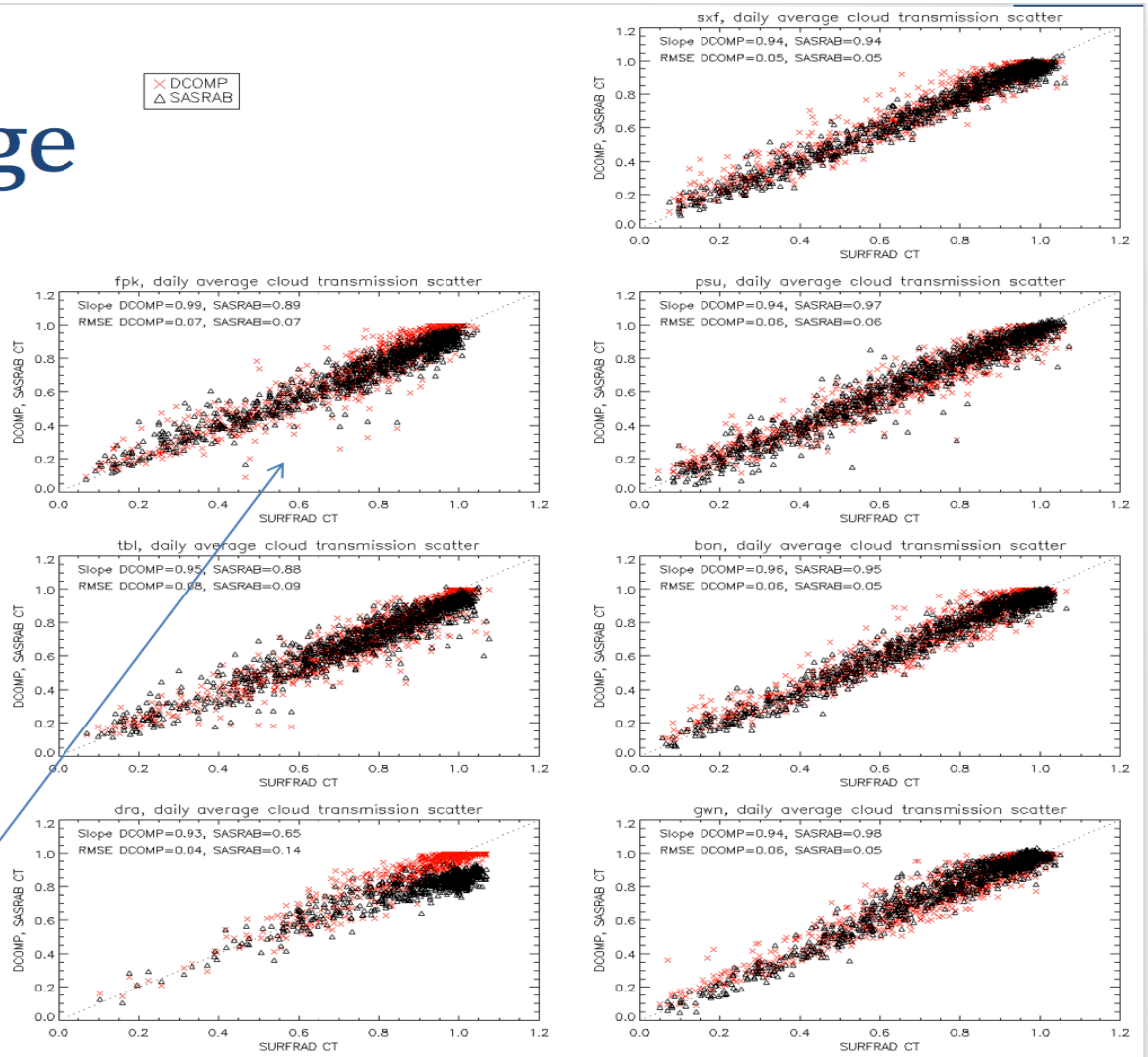
DCOMP/VIIRS Rain Rate



Daily Average CT, 2005-2011

DCOMP – CT direct from DCOMP
SASRAB – CT calculated from SASRAB GHI and B&H CSI
SURFRAD – CT calculated from observed GHI and B&H CSI

Waterfall below 1:1 line goes away if you compare only May-Oct. Probably snow effects. RMSE decreases, too.



SURFRAD/DCOMP cloud comparisons by Christine Molling

- **Product retrieval improvements:**
  - Use of higher resolved I-band for COD and REF at daytime
  - Near-IR only retrievals for REF over very bright surfaces (e.g. Greenland)
  - Improvements for regions and periods with highly variable snow extent
  - Optional processing of all pixel processing (no consideration of cloud mask)
  - Include Multi-layer forward model
  - Include NLCOMP, a DNB/M12-based nighttime algorithm
  - Include lunar reflectance
- **Application additions:**
  - Rain probability
  - Rain rate
  - Rain probability Night
  - Rain rate Night
  - Icing threat parameters
  - Cloud transmission

What could be in a future operational algorithm?

- **Product retrieval improvements:**
  - Use of higher resolved I-band for COD and REF at daytime S C
  - NIR-only retrievals for REF over very bright surfaces (e.g. Greenland) S C D
  - Improvements for regions and periods with highly variable snow extent D T
  - Optional processing of all pixel processing (no consideration of cloud mask) S C
  - Include Multi-layer forward model D O
  - Include NLCOMP, a DNB/M12-based nighttime algorithm C O
  - Include lunar reflectance S, C
- **Application additions:**
  - Rain probability SD
  - Rain rate D T
  - Rain probability Night SD O
  - Rain rate Night D T O
  - Icing threat parameters D
  - Cloud transmission C S

S possible in a short time (1 year)
C Already included in CLAVR-x (or development branch)
D more development work needed
O not 100% suitable for operational processing
T technically (software) challenging

Thank you!