Current State of GOES-R ABI and NPP/JPSS AWG VIIRS Cloud Algorithms

Andrew Heidinger: NOAA/NESDIS@CIMSS
+ The GOES-R AWG Cloud Team
+ The nascent JPSS Cloud Team

NOAA Science Week
2012 Kansas City, MO

Outline

1. Review of AWG Algorithms and Validation Status
2. Cloud Algorithm Contributions to JPSS Risk Reduction
3. Current Applications of AWG Cloud Products

GOES-R AWG Cloud Team (*and ABI-VIIRS JPSS Risk Reduction*)

- Andrew Heidinger – NOAA / NESDIS
- Patrick Minnis – NASA / Langley
- Michael Pavolonis – NOAA / NESDIS
- Pat Heck – UW/CIMSS (formerly NASA / Langley)
- Andi Walther – UW/CIMSS
- Ping Yang – Texas A&M
- William Straka and others – UW/CIMSS

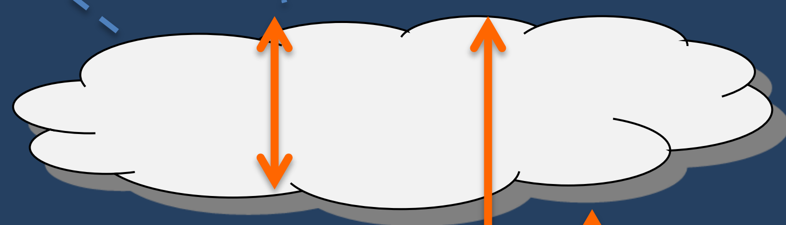
Most cloud algorithms have been coded by Harris and have met their reproducibility requirements.

The GOES-R/JPSS Cloud Product Suite

μ-physics
Cloud Phase
Cloud Type
Particle Size

mass
Cloud Optical Depth
Liquid Water Path
Ice Water Path
Cloud Emissivity

macro–physics
Cloud Top Height
Cloud Top Temperature
Cloud Top Pressure



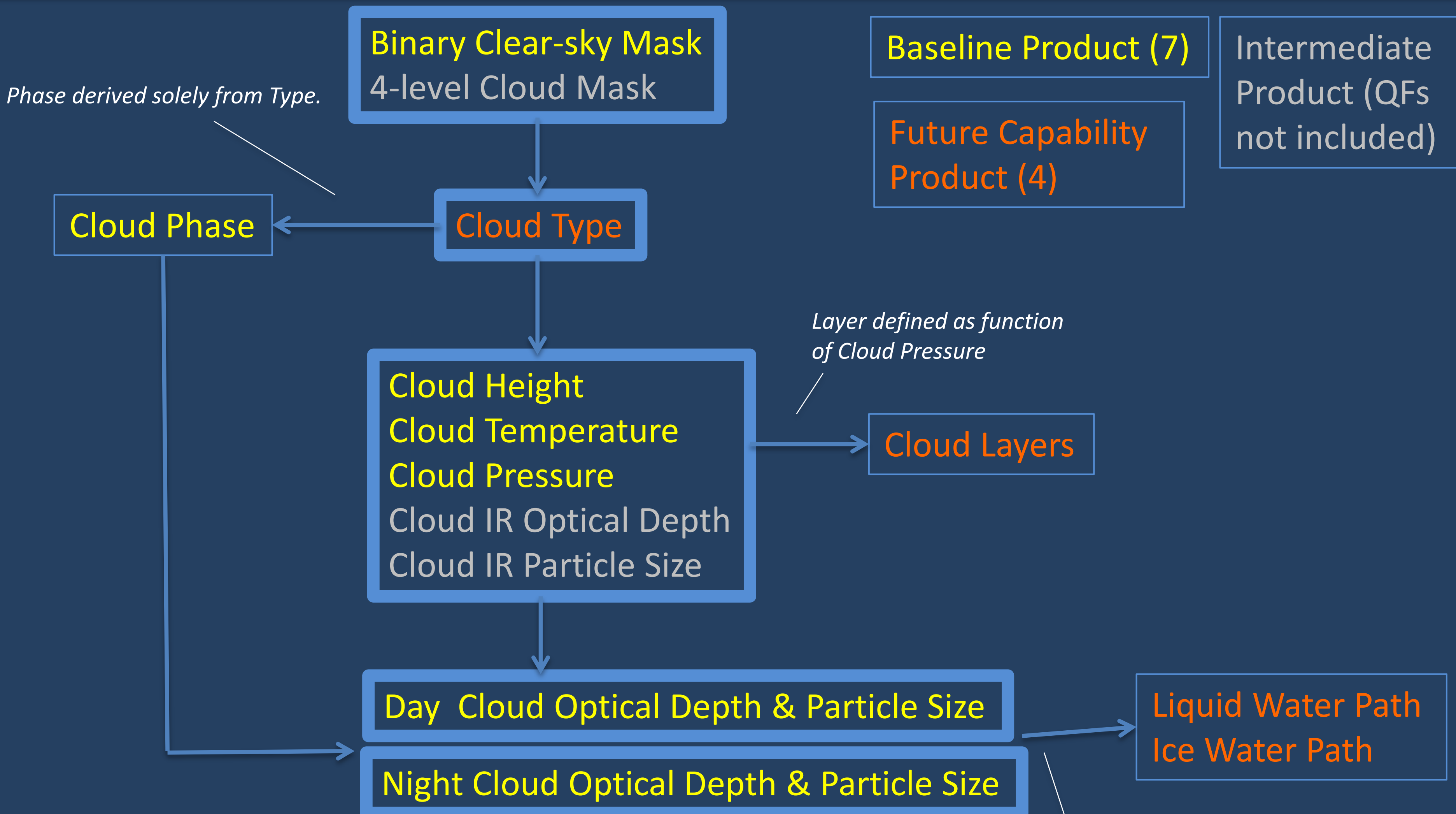
Cloud Base Height

Products we don't make:
Temporal changes.
Horizontal size.
Multiple layer solutions.
Meteorological types.

Also included:
Cloud Detection
Cloud Cover by Layer

1. Review of AWG Algorithms and Validation Status

Relation of AWG Cloud Baseline and Future Capability Products



Future Capability products are included automatically in the 5 baseline cloud algorithms. No additional research is directed for them.

Cloud Detection

AWG Cloud Mask (ACM) Overview

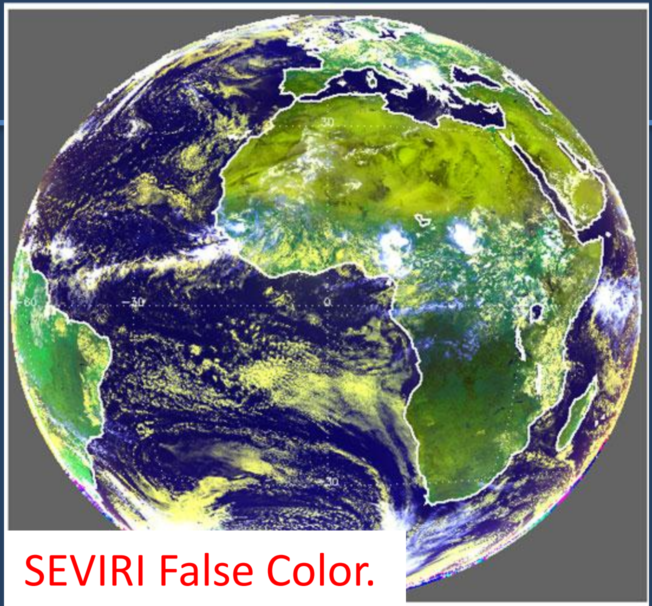
- Based on past experiences with trying to serve a common mask to multiple applications, we decided to maximize flexibility above all else.

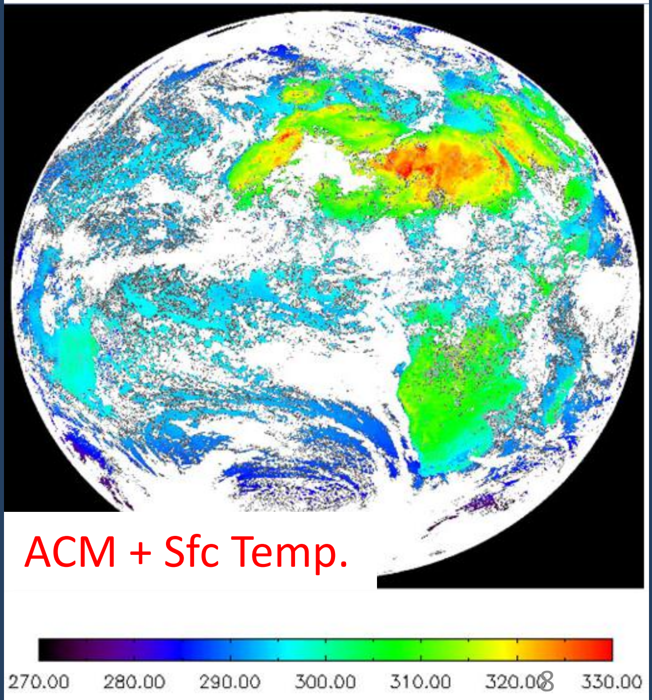
- ***Our solution was to build a mask with multiple individual tests that could turned on and off by the downstream applications. This allows a common mask to be optimized.***

- In addition, the design allows for additional of new tests easily as warranted.

- Individual tests were taken from various cloud masks developed by the team.

- Determination of test thresholds accomplished through an analysis of CALIPSO data.

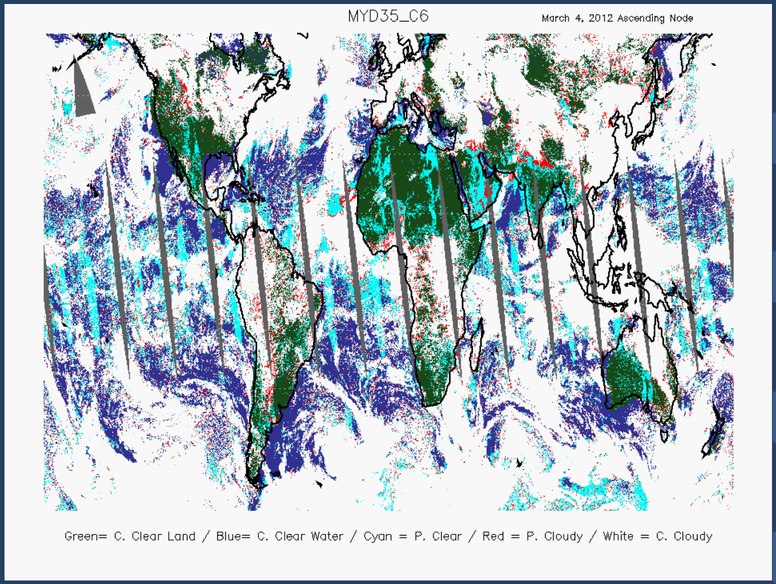

SEVIRI False Color.



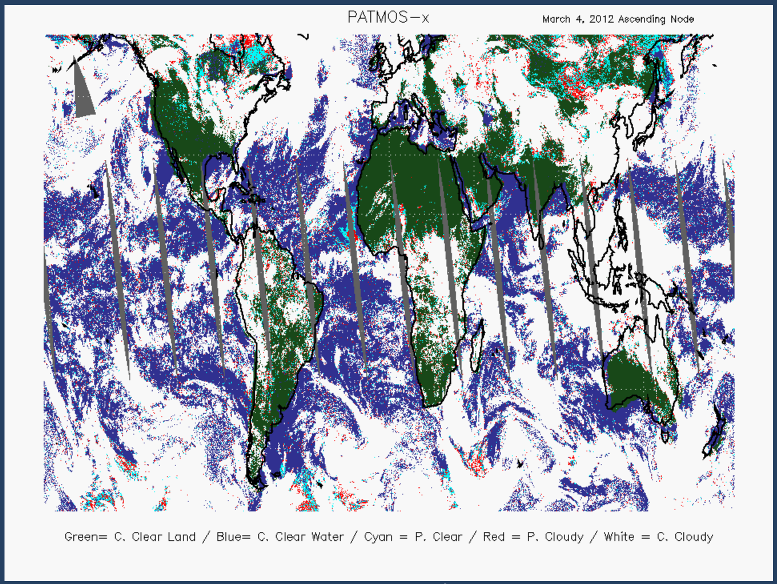
ACM + Sfc Temp.

Extension of ACM to Other Sensors

AQUA/MODIS MYD35 Collection 6



ACM run on AQUA/MODIS



Clear Ocean

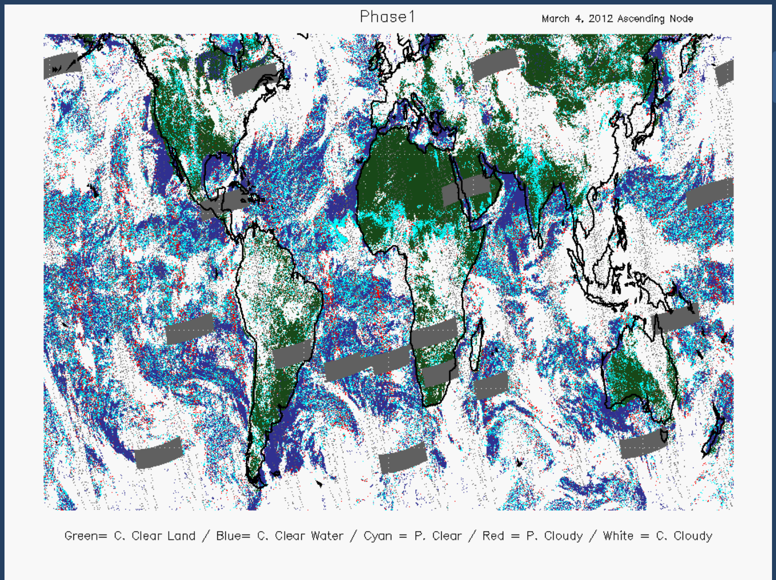
Clear Land

Prob. Clear

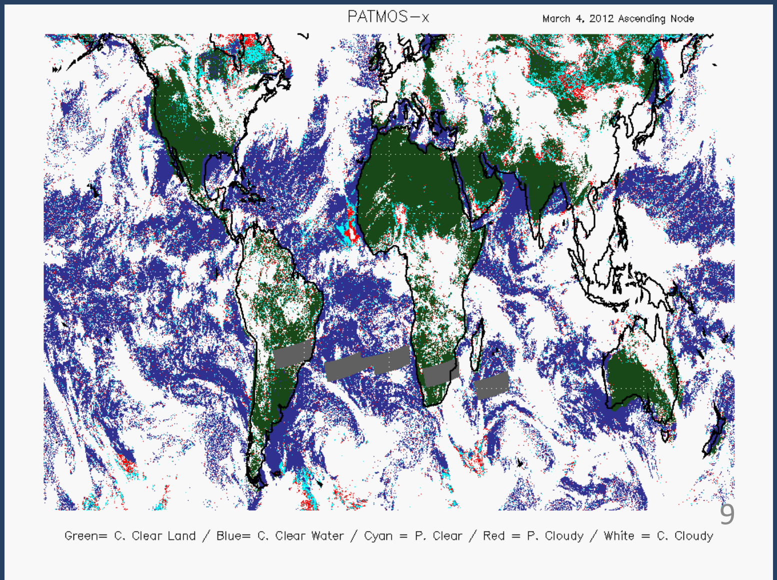
Prob. Cloudy

Cloudy

NGAS VCM run on NPP/VIIRS



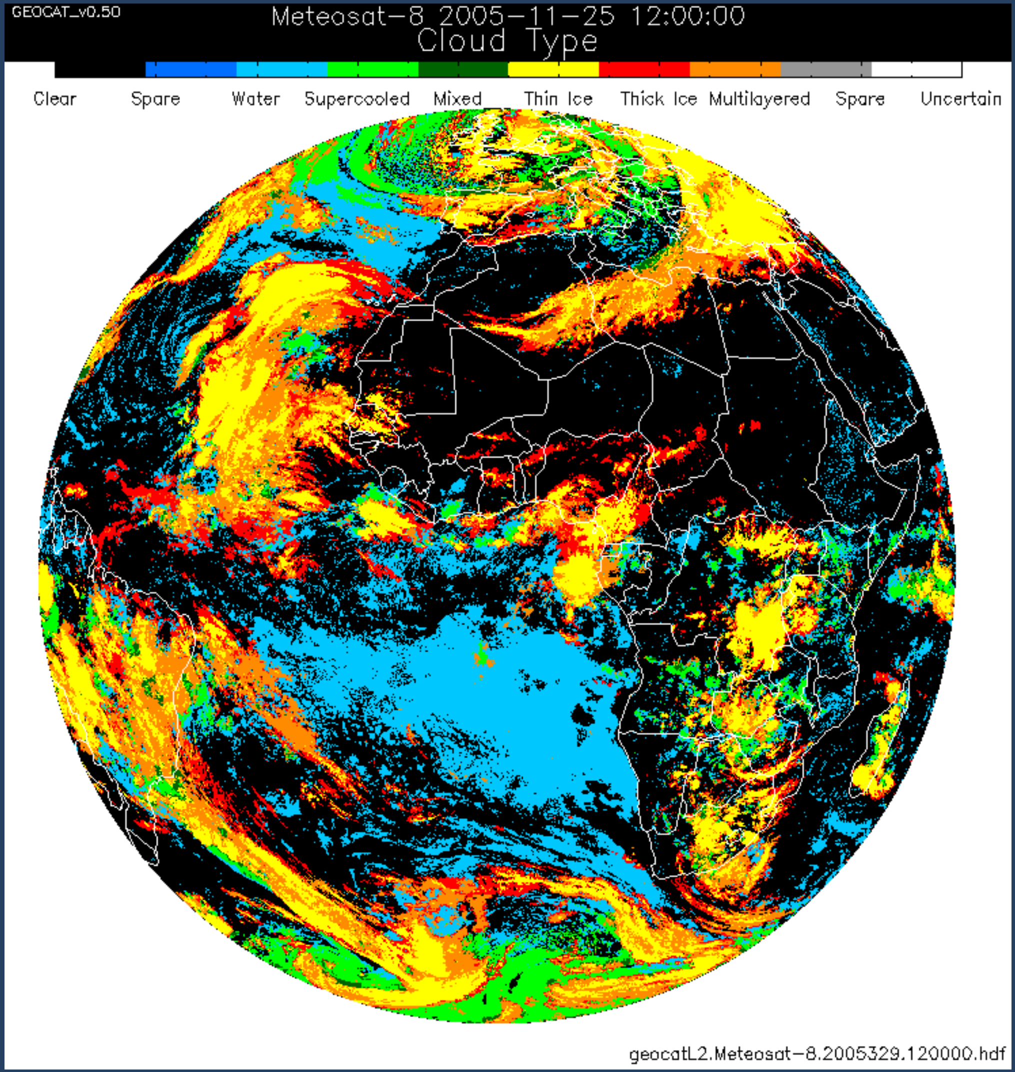
ACM run on NPP/VIIRS



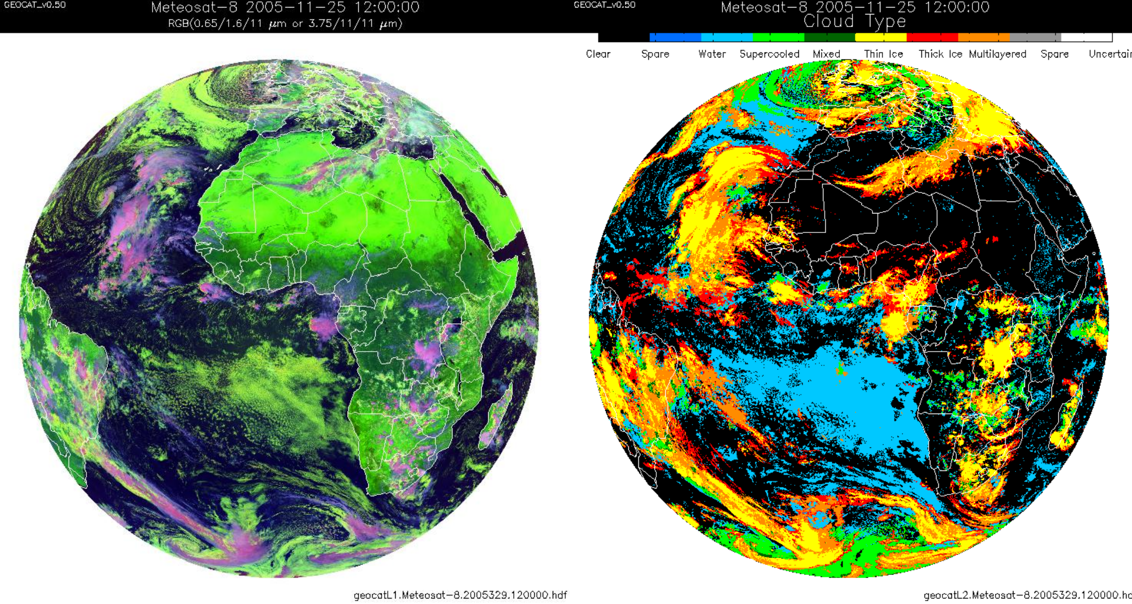
Cloud Phase

AWG Cloud Phase/Type Overview

- Cloud Phase/Type
  - An Infrared only algorithm that exploits the rich IR information provided by the ABI and the recent improvements in fast clear-sky radiative transfer models and ancillary data.
  - In addition, advanced use of spatial information is a large part of this algorithm.

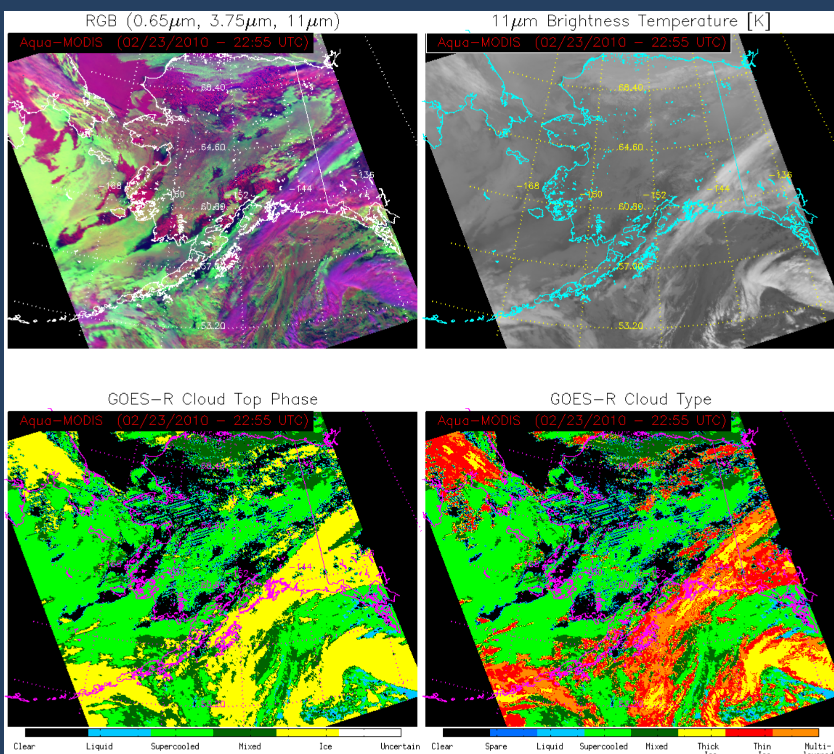


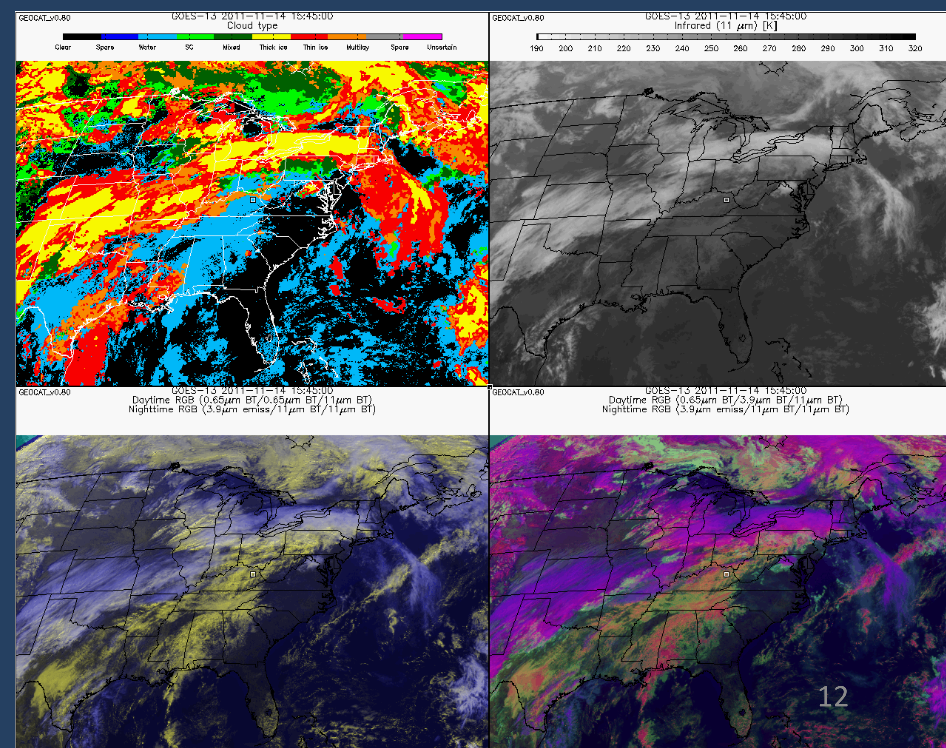
Mike Pavolonis, NOAA



- •The GOES-R cloud phase is generated in near real-time using SEVIRI (top,left), MODIS (bottom, left), and GOES (bottom, right)
- •The GOES-R approach can also be applied to MTSAT and VIIRS

Mike Pavolonis, NOAA

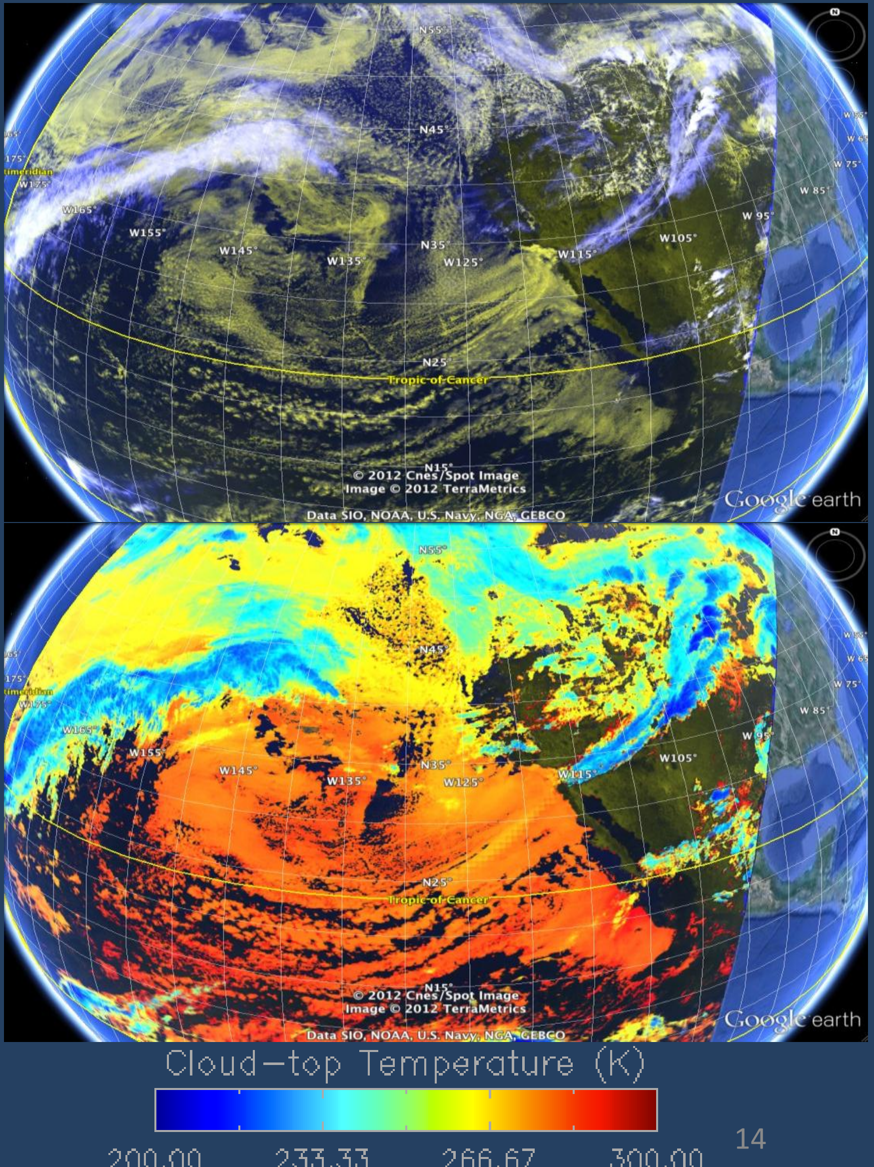




Cloud Height

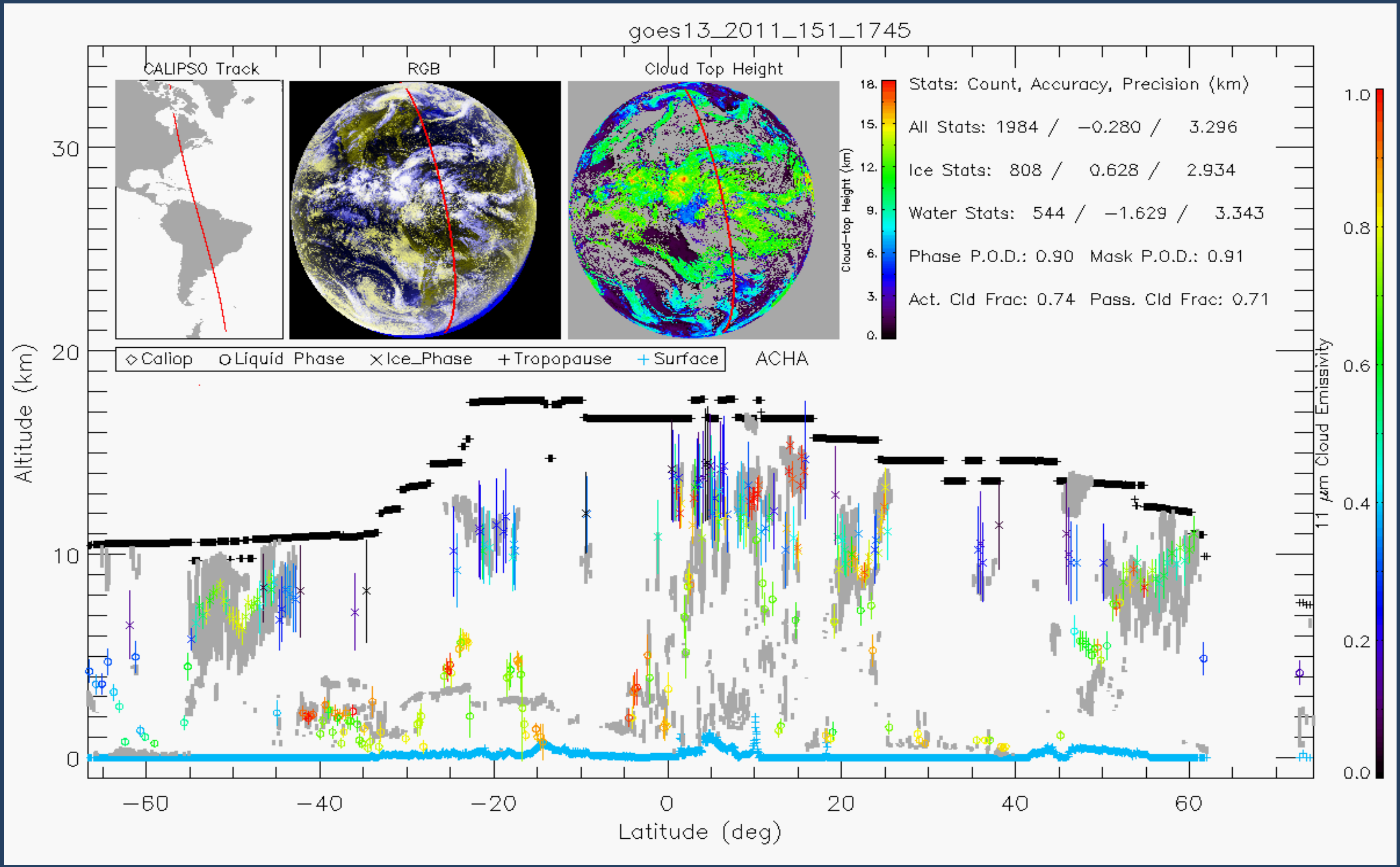
AWG Cloud Height Algorithm (ACHA) Overview

- Algorithm uses the 11, 12 and 13.3 μm channels for ABI, other channels for other sensors.
- An optimal estimation approach is used to estimate cloud temperature, cloud emissivity and a cloud microphysical index.
- Cloud pressure and height are computed from NWP profiles.
- Special processing occurs in the presence of inversions.
- A multi-layer solution is performed for pixels typed as multi-layer.



ACHA Validation: GOES-13 vs. CALIPSO/CALIOP

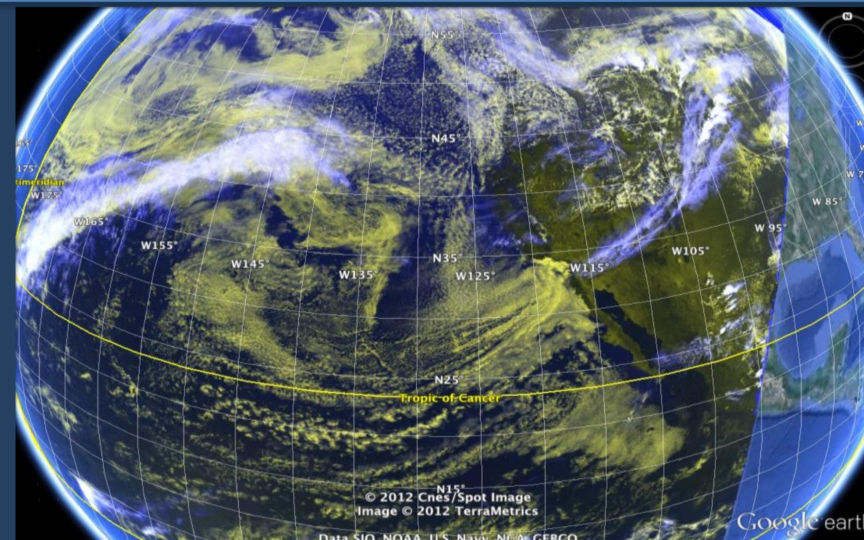
- ACHA has been modified to operate on GOES, AVHRR, MTSAT, SEVIRI, MODIS and VIIRS
- CALIPSO/CALIOP Validation Tools also extended to include these sensors.

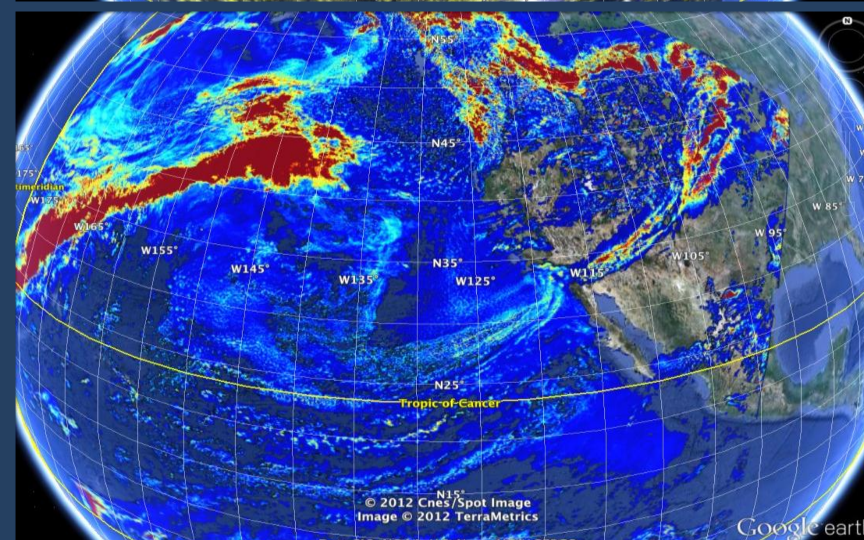


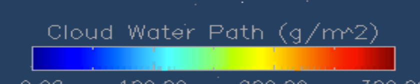
See poster by Holz et al (W-25)

Daytime Cloud Optical and Microphysical Properties (DCOMP)

- Optical depth and particle radius are estimated simultaneously. IWP and LWP are derived from optical depth and particle size.
- Optimal estimation approach – provide automatic error estimates.
- Baseline channels uses are 0.65 μm and 2.2 μm reflectances.
- We implemented state-of-the-art scattering models that are consistent with those run by the NASA Goddard MODIS products.
- We implemented atmospheric correction and surface reflectance models provided by the MODIS Science Team.

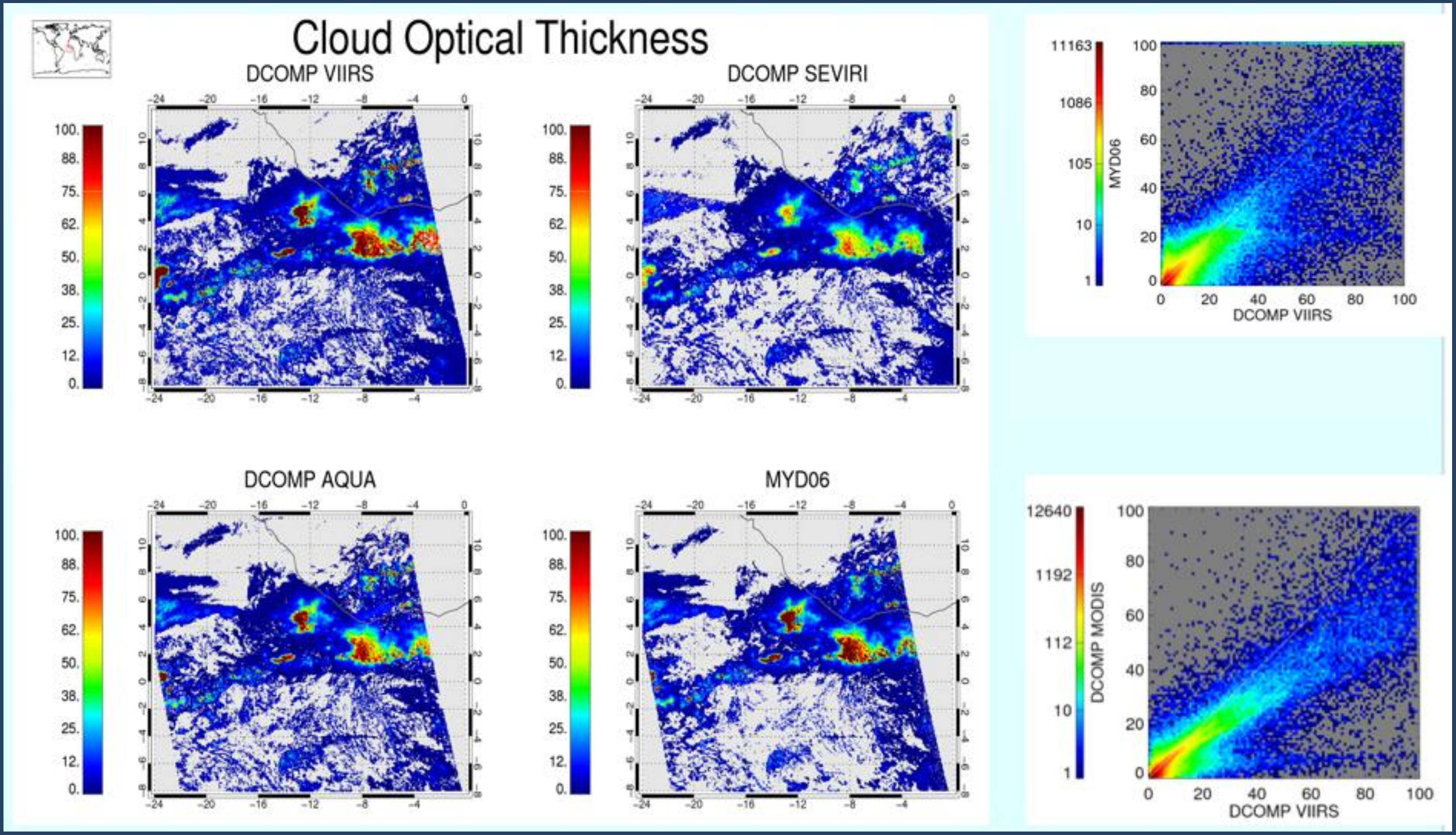






Andi Walther, CIMSS (see poster W-5)

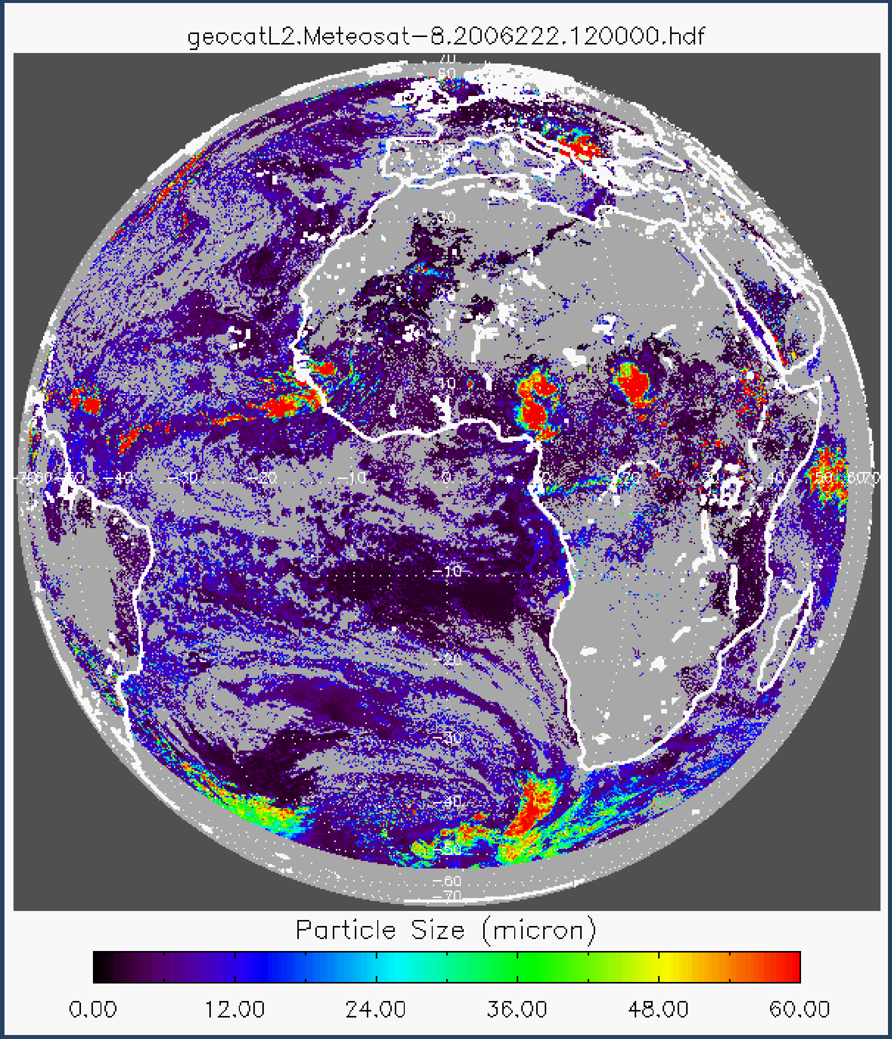
DCOMP Intra-Sensor Consistency Example



COD is in general in a good agreement between DCOMP on different sensors and the MAST/MYD06 product..

Nighttime Cloud Optical and Microphysical Properties (NCOMP)

- Algorithm uses the 3.90, 8.5, 11 and 12 μm channels.
- Similar to daytime, an iterative approach is used to estimate optical and particle size. IWP and LWP are derived from optical depth and particle size.
- ABI version will benefit from improvements developed by NASA/Langley (Pat Minnis) during the AWG lifetime.

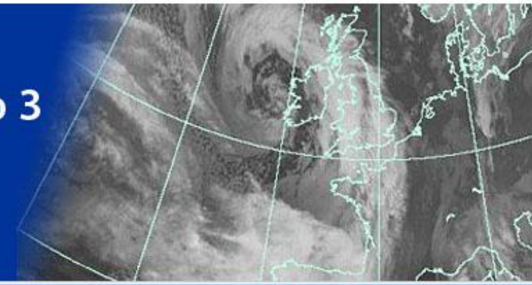


Validation by Consensus: The EUMETSAT Cloud Retrieval Evaluation Workshops (CREW)

- CREW is a EUMETSAT sponsored series of workshops devoted to detailed evaluation of cloud products.
- Participants have to submit their data <u>before</u> the meeting for specific scenes that span interesting conditions.
- A Eumetsat-funded scientist does a <u>standard analysis</u> for all the submitted data sets.
- Third Meeting held in Madison, WI in Nov. 2011. Chaired by Rob Roebeling (KNMI) and Bryan Baum (UW)

2011 EUMETSAT Cloud Retrieval Evaluation Workshop 3

15-18 November
Madison, WI



Accommodations | Agenda | Madison | Meeting Site | Registration

Return to CREW-3 Wiki

Madison

Set on an isthmus between two scenic lakes, the city of Madison is Wisconsin's second largest city and the state capital. Madison is home to many different attractions including the State Street pedestrian mall, many restaurants, great lakes, world class bike paths, great museums and galleries and so much more. In addition to this list of possible activities and notable places, more information about Madison can be found on the Visitors Bureau web site.

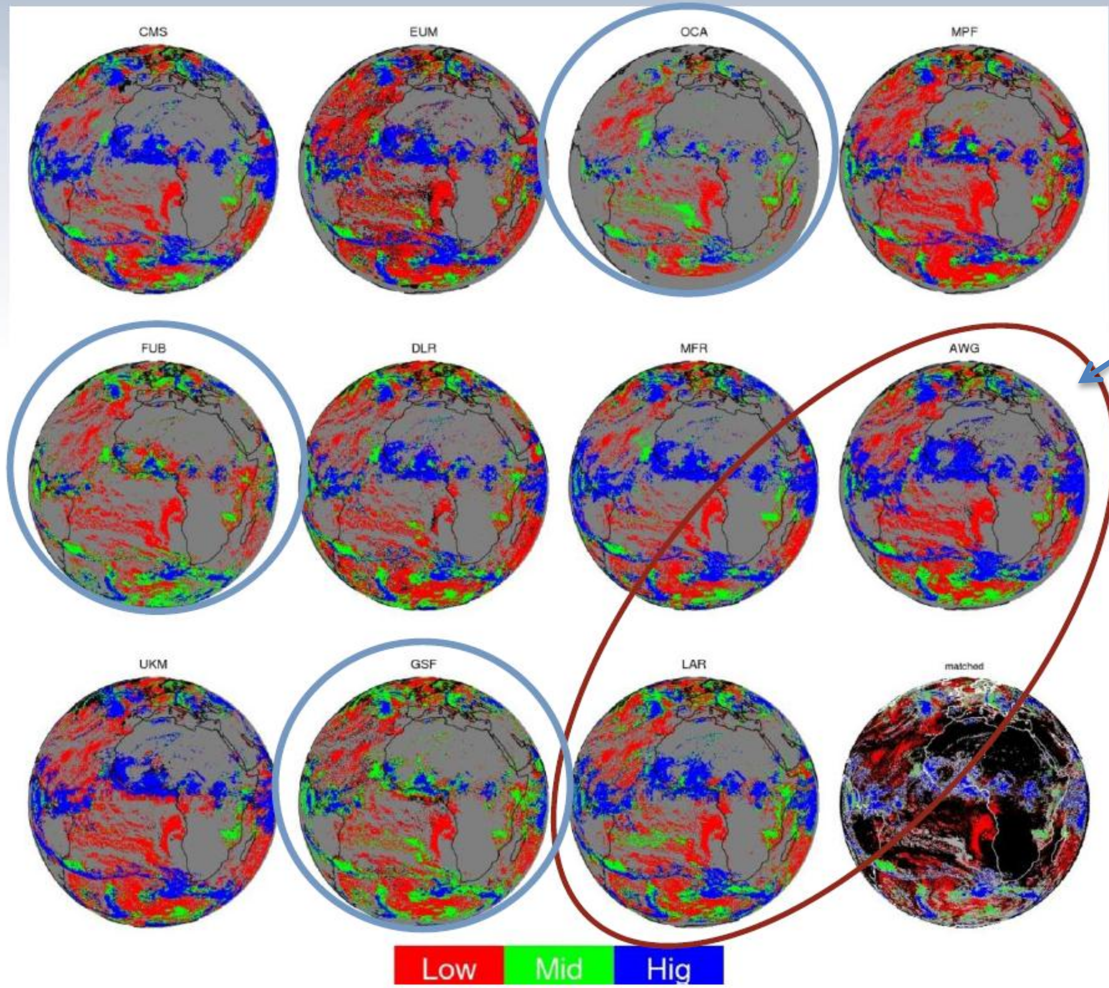
Travel Information

The City of Madison is served by most major airlines at the Dane County Regional Airport (MSN), located approximately 10 km from the city center. Transportation from the airport to the Lowell Center is available by Taxi (for approximately $25). If you are staying in a hotel other than the Lowell Center, please use the free courtesy phones in the airport, located both on the arrivals concourse and in the middle of the baggage claim area, to contact the hotel to send a free shuttle.

If you are flying through O'Hare Airport (ORD) or Midway (MDW) in Chicago and your flight is delayed, there is an excellent bus service directly from these airports to the Memorial Union, just 1 block from the Pyle Center. The cost is approximately $30 US one way.

AWG Products submitted to CREW and CREW reports document their performance relative to others

Example: MSG inter-comparison



AWG = G
Algorithr
Working

Fig. : *Cloud top pressure of 12 MSG algorithms (13 June 2008, 12 hr UTC)*

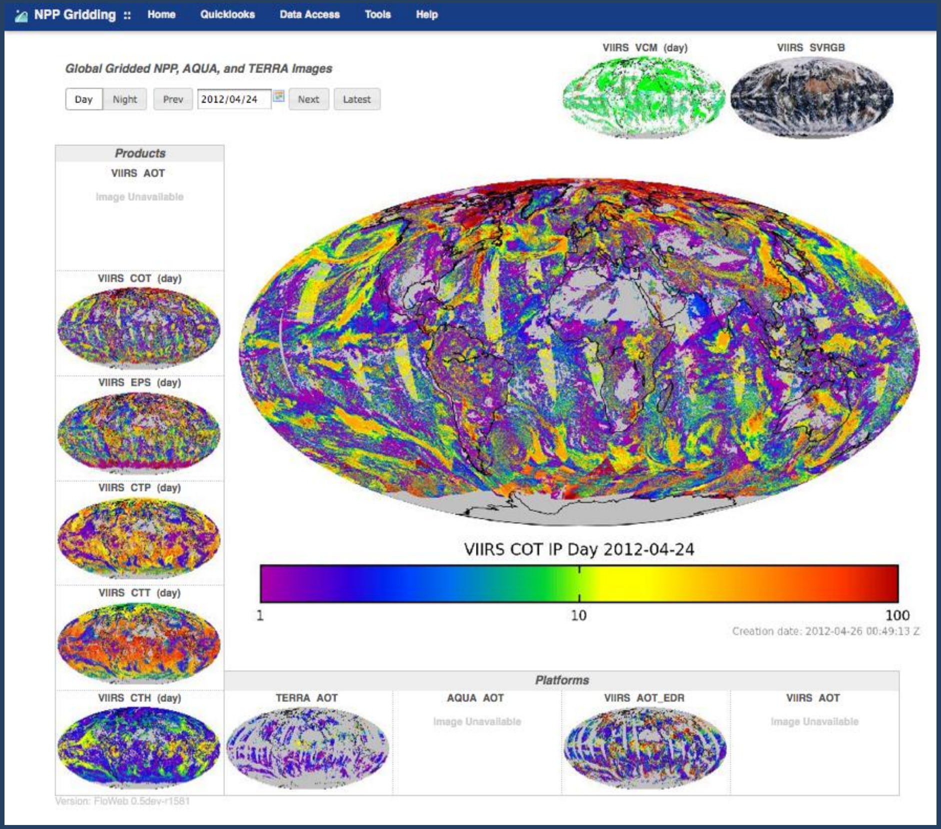
Comparison against Calipso/Cloudsat: Cloud Top Heights

	CTT [K]	CPH	CTH [m]	CTH [m] Seviri vs CPR			CTH [m] Seviri vs Calipso		
Mod	Median Seviri	[% wtr] Seviri	Median Seviri	Bias	RMSE	Corr	Bias	RMSE	Corr
CMS	256.0	44.2	7434	-1061	2504	0.75	-527	1801	0.88
EUM	234.8	41.1	8264	-647	2260	0.75	-98	1726	0.87
OCA		96.7	6802	-1183	2347	0.77	-573	1712	0.90
MPF	240.9	30.1	7789	-1138	2486	0.78	-633	1591	0.91
FUB	-	-	5665	-991	2916	0.70	-463	2098	0.85
DLR	250.8	23.8	6043	-1676	2794	0.75	-1156	1922	0.90
MFR	235.9	42.6	7965	-942	2574	0.72	-402	1941	0.85
AWG	238.8	31.2	7784	-631	2165	0.75	-97	1592	0.90
UKM	237.5	37.1	7732	-742	1881	0.86	-56	1862	0.86
GSF	tbc	tbc	tbc	tbc	tbc	tbc	tbc	tbc	tbc
LAR	244.3	40.7	7751	-1090	2464	0.76	-516	1849	0.87

The JPSS CAL/VAL Team

- Andrew Heidinger – NOAA / NESDIS
- Bob Holz – UW/SSEC
- Dan Lindsey – NOAA/NESDIS
- Michael Pavolonis – NOAA / NESDIS
- Steve Miller - CIRA
- Jay Mace - University of Utah
- Andi Walther – UW/CIMSS
- Min Min Oo – UW/CIMSS

UW/SSEC PEATE web-site



This team's mission is to access the NPP IDPS algorithms and work towards improving them for JPSS

Cloud Contributions to JPSS Risk Reduction

Uniform Multi-Sensor Algorithms for Consistent Products

Led by Walter Wolf, NESDIS/STAR

JPSS ABI to VIIRS Risk Reduction Project Overview

- NOAA/NESDIS decided to port several GOES-R AWG algorithms to VIIRS and process them within NDE as NOAA Unique Products.
- The benefits of doing this are algorithm consistency across GOES-R and JPSS (as noted by NWS objectives for NEXGEN)
- Will demonstrate cost effective processing of JPSS products.
- Demonstration of NOAA’s goal of enterprise solutions by employing same algorithms for “POES” and “GOES”
- Supports NWS OS&T implementation strategy of multi-sensor algorithms and products

GOES-R & VIIRS Cloud Product Overview

Product Sensor	IDPS VIIRS	AWG ABI	NESDIS Ops (AVHRR and GOES-Imager)
mask	□	□	□
phase	□	□	□
type	□	□	□
top height	□	□	□
top temperature	□	□	□
top pressure	□	□	□
base height	□		
cover by layers	□	□	□
optical depth	□	□	□
effective particle radius	□	□	□
liquid water path		□	□
ice water path		□	□

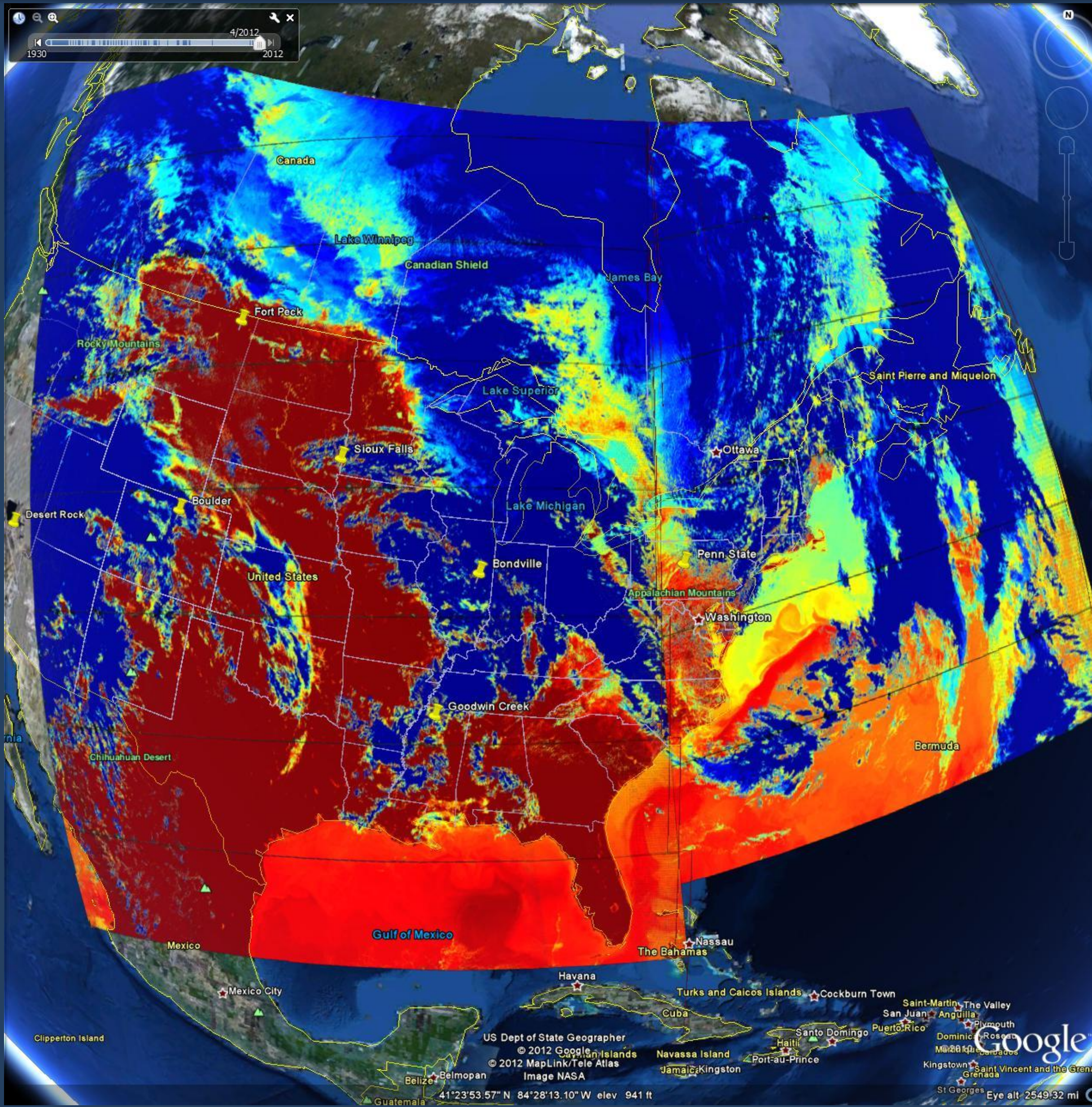
Porting GOES-R AWG Cloud Algorithms to JPSS/VIIRS

In general, there are no major obstacles preventing the porting of the GOES-R AWG cloud algorithms to VIIRS. However, there are some specific issues that will be addressed.

- ***Cloud Mask***: GOES-R ABI Cloud Mask lacks polar-specific cloud detection thresholds. DNB offers area of research (*proposal submitted to JPSS Risk Reduction*).
- ***Cloud Type***: VIIRS lacks water vapor and co_2 absorption bands. This will likely impact accuracy of multilayer detection.
- ***Cloud Height***. VIIRS lacks water vapor and co_2 absorption bands. This will impact accuracy of heights for thin cirrus and multi-layer conditions. Generation of cloud base is straight forward though highly uncertain.
- ***Daytime Cloud Optical and Microphysical Properties (DCOMP)***: No issues though VIIRS does offer the 1.24 μm channel which allows for accurate retrievals over snow.
- ***Nighttime Cloud Optical and Microphysical Properties (NCOMP)***: No issues.

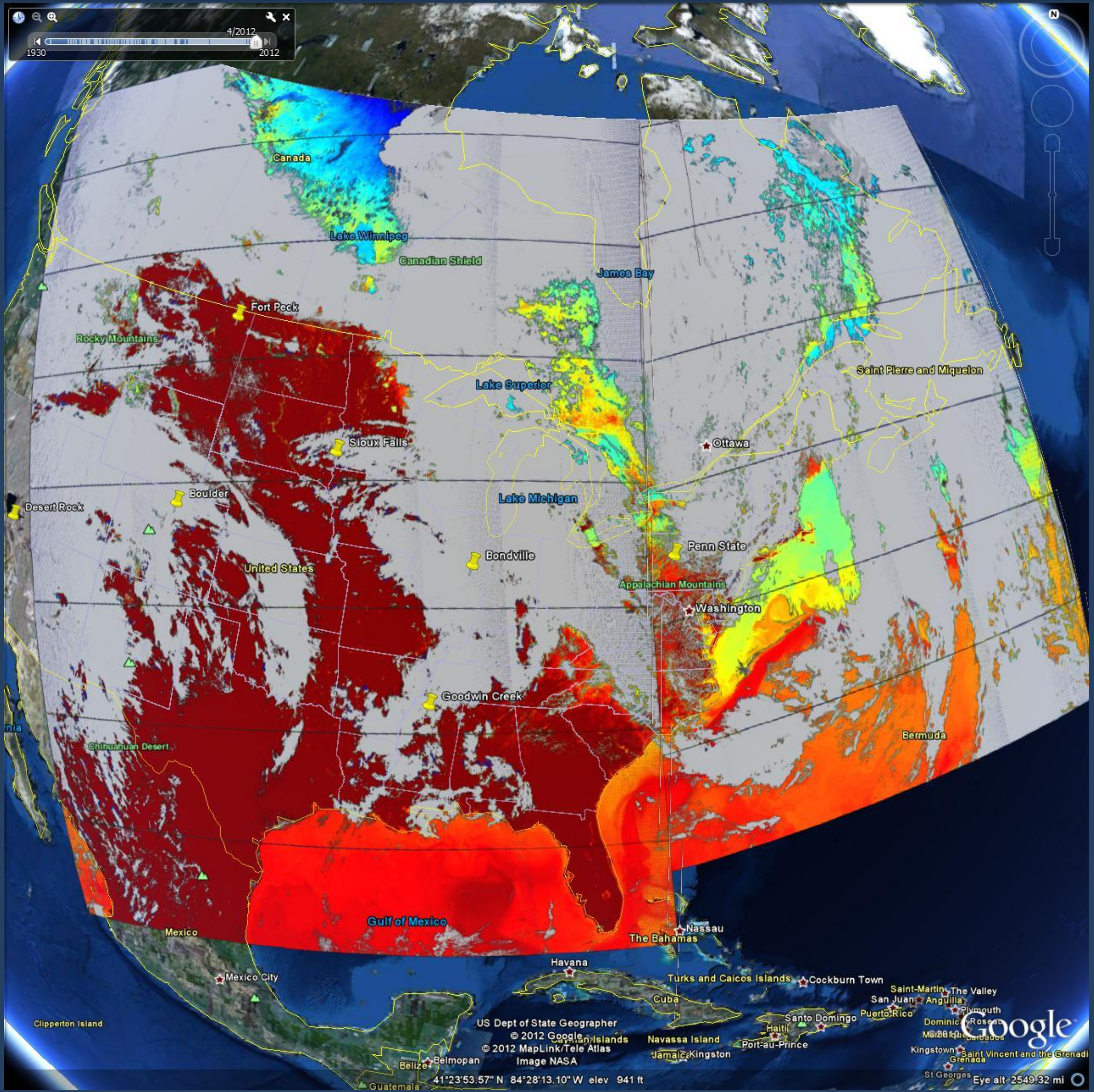
Application of ACM to VIIRS in Real-time Using UW/SSEC DB Data

- UW/SSEC DB VIIRS sdr data is now available in real-time.
- We are beginning to apply our own cloud algorithms in preparation for the JPSS Risk Reduction.
- Image on the right shows a Google Earth composite of UW/SSEC DB data from two afternoon passes.
- Data shown is surface temperature derived for all pixels without any cloud mask filtering.



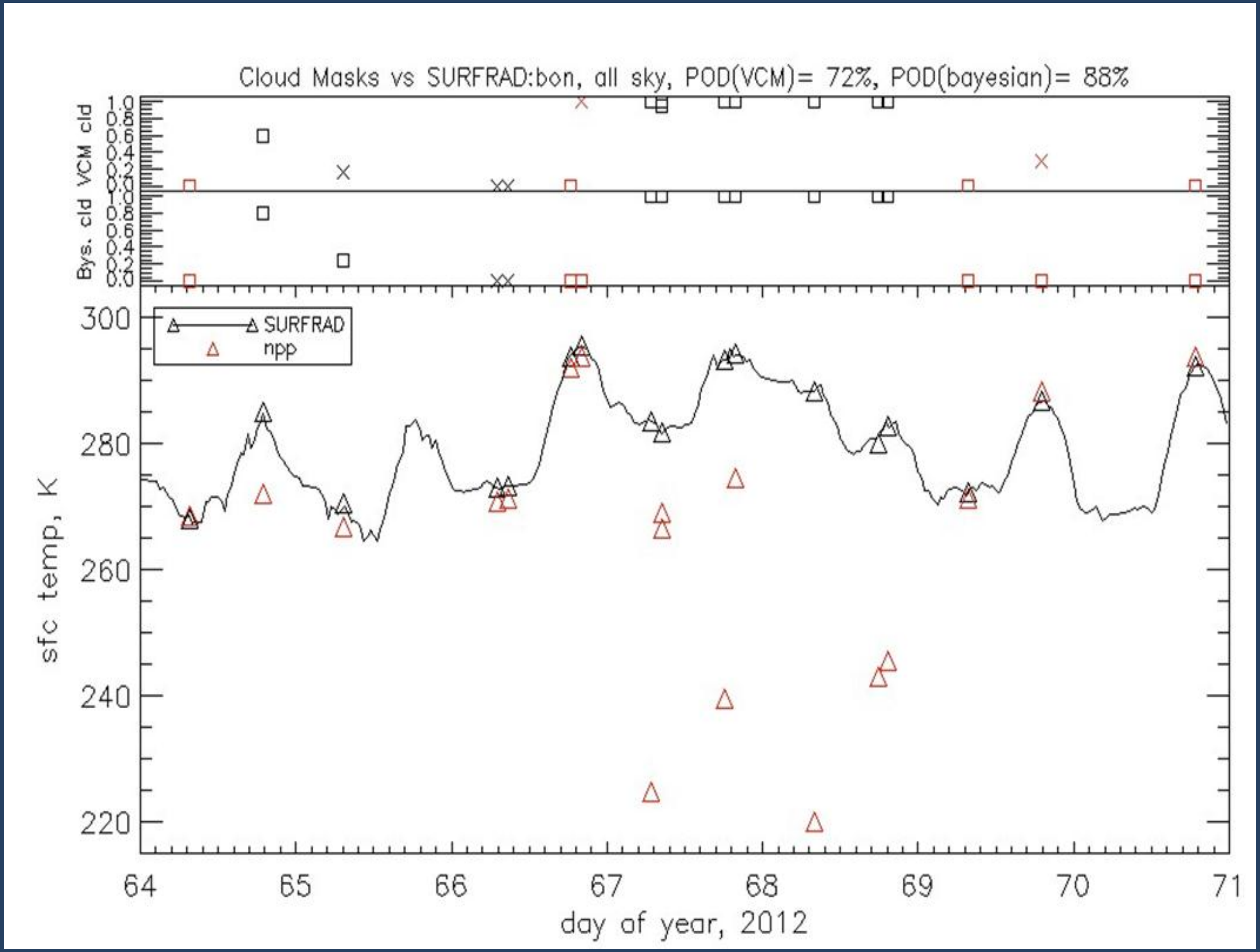
Application of ACM to VIIRS in Realtime Using UW/SSEC DB Data

- Image on the right shows the surface temperature with the cloud mask overlaid.
- Grey areas are pixels that are cloudy or probably cloudy.
- Comparison with SURFRAD Stations (pins) are being used to verify our cloud products including detection.
- These analysis are part of our product monitoring are online now.



Application of ACM to VIIRS in Realtime Using UW/SSEC DB Data

- The SURFRAD sites provide a surface temperature product at several sites. Clouds look cold.
- Figure on the right shows time-series for one week of VIIRS and SURFRAD surface temps for Bondville, IL.
- Results show that clouds are detected when VIIRS and SURFRAD surface temperatures deviate.
- Top panel shows cloud fraction from VIIRS using VCM and ACM

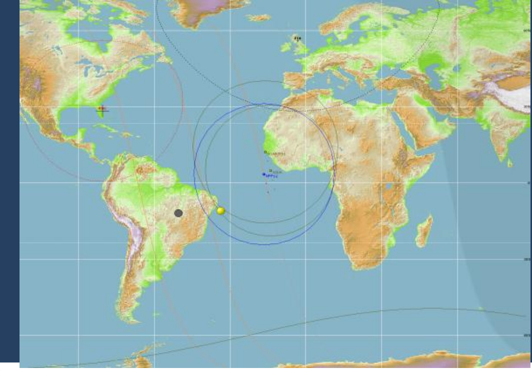


See Poster W-18, Denis Botambekov

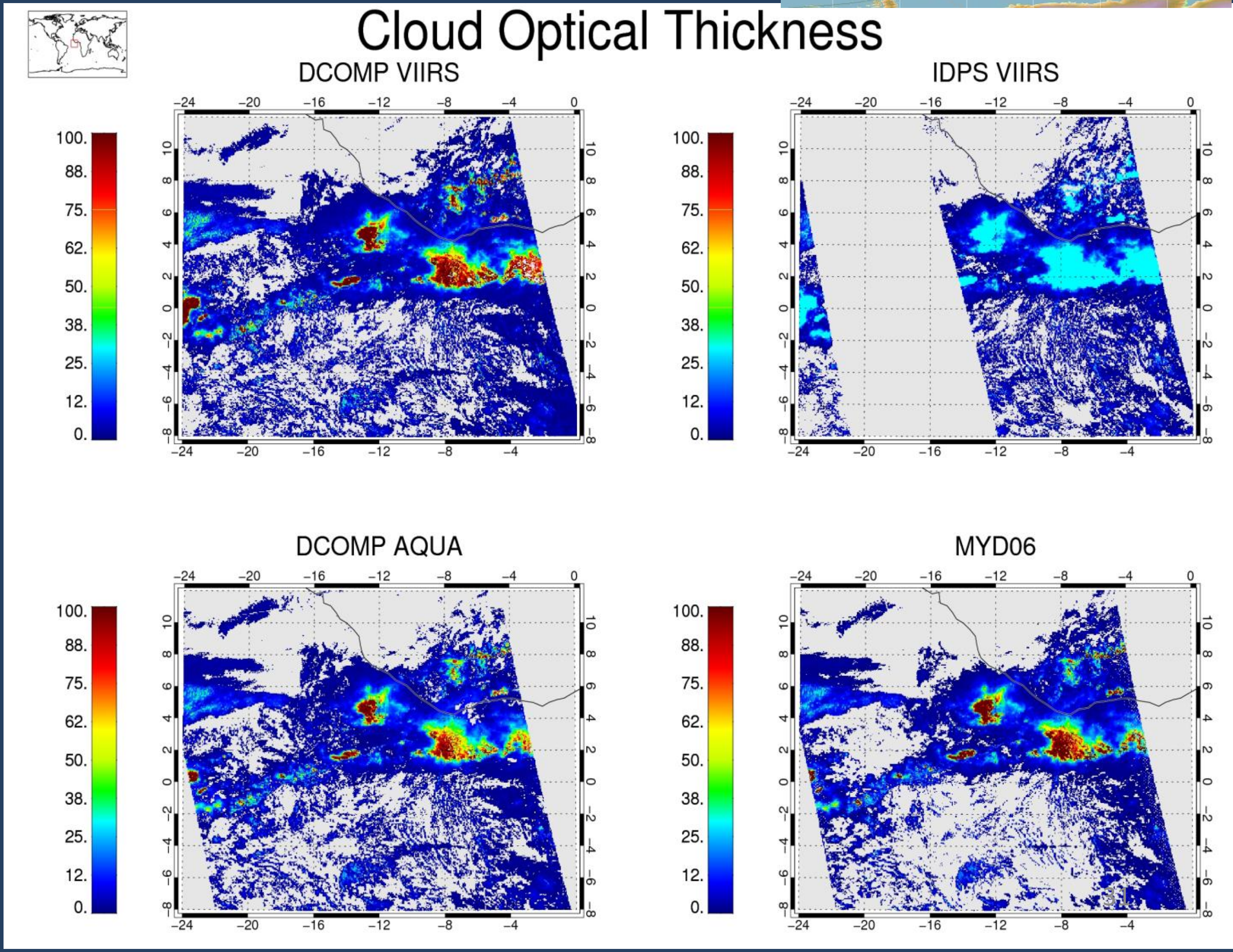
Cloud Phase JPSS Activities

- Evaluation of the operational VIIRS cloud phase flag (Pavolonis and Heidinger, 2004; Pavolonis et al., 2005), including comparisons to the GOES-R approach
- Apply the GOES-R approach to VIIRS, validate, and transition to NESDIS operations

DCOMP JPSS Activities: Example of DCOMP on VIIRS: Cloud Optical Thickness (COT)



- March 4, 2012 offered a nice amount AQUA/NPP matchups.
- We don't really have any independent validation of cloud optical thickness (COT). But comparisons with other algorithms are enlightening.
- Note, IDPS skips glint.
- Here we show IDPS VIIRS with NASA MYD06 and NOAA DCOMP. DCOMP runs on both MODIS and VIIRS data so it acts as a transfer standard here.
- Major artifact with IDPS VIIRS is the limit of 30.
- Correlation of results for COT < 30 not too bad.



Current Applications of AWG Cloud Products

Relation of AWG Cloud Products to Other AWG Products

- Clear-sky Mask → All cloud products, soundings, SST, Snow cover, Aerosols, others
- Cloud Phase/Type → Aviation Icing
- Cloud Height → Atmospheric Motion Vectors + Aviation Icing
- Day Cloud O&M Props → Aviation Icing + Fog
- Night Cloud O&M Props → Aviation Icing

Relation of AWG Cloud Products to Other Non-AWG Products

Clear-sky Mask → Proving Ground | Sky Cover Estimates

Cloud Phase/Type → CIMSS Convective Initiation | Proving Ground

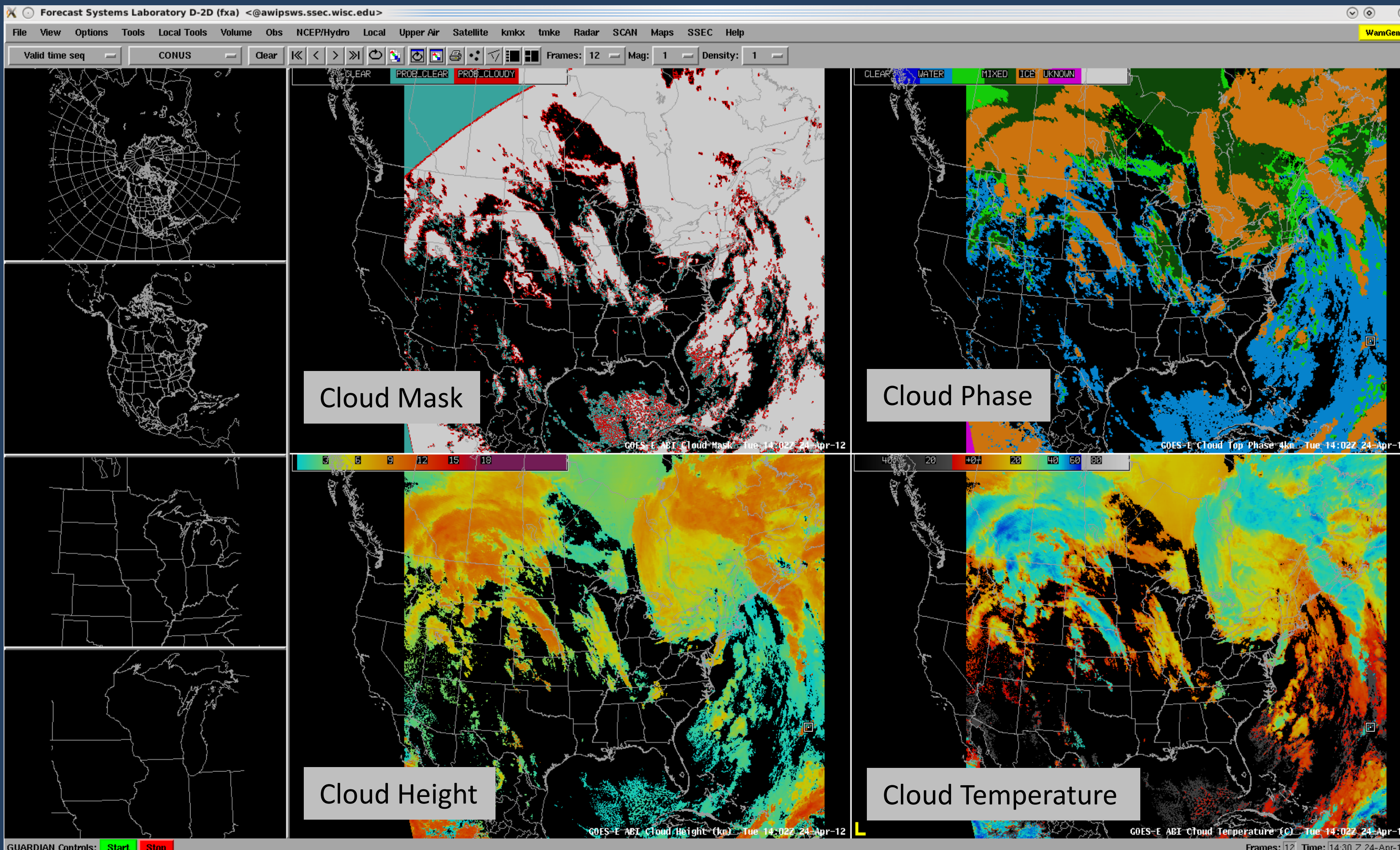
Cloud Height → Proving Ground | Alaska NWS Composites | Aviation | RR Assimilation | Field Campaigns (TORERO, DC-3)

Day Cloud O&M Props → Solar Energy Forecasters via NREL | Great Lakes Snow

Night Cloud O&M Props → Served by NASA Langley (SIST)

Supported Sensors: GOES/Imager, AVHRR and MODIS

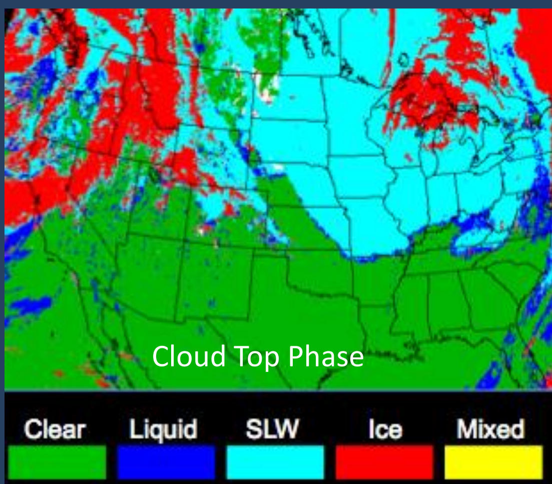
Proving Ground: AWG Cloud Products using GOES Served in AWIPS

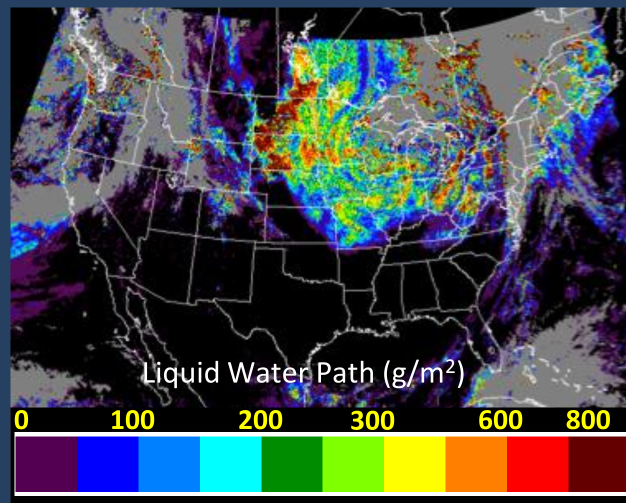


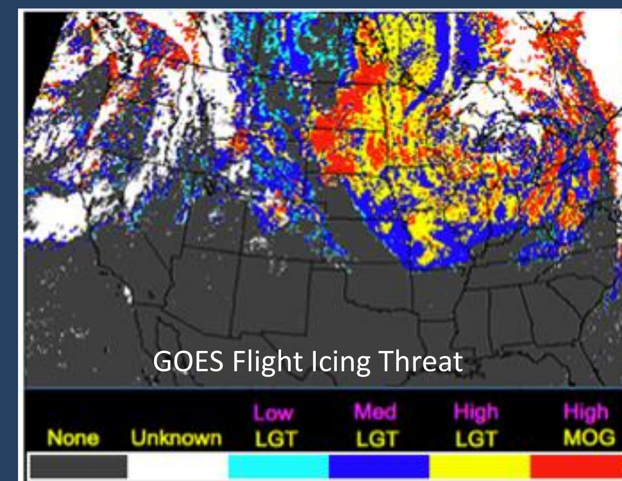
William Straka, CIMSS

Satellite-derived Cloud Parameters Correlate with Aircraft Icing

- Satellite data provide critical information (and resolution) unavailable from other sources
- Retrieved **cloud phase, LWP, R_e** are basis for a satellite Flight Icing Threat (FIT) Algorithm

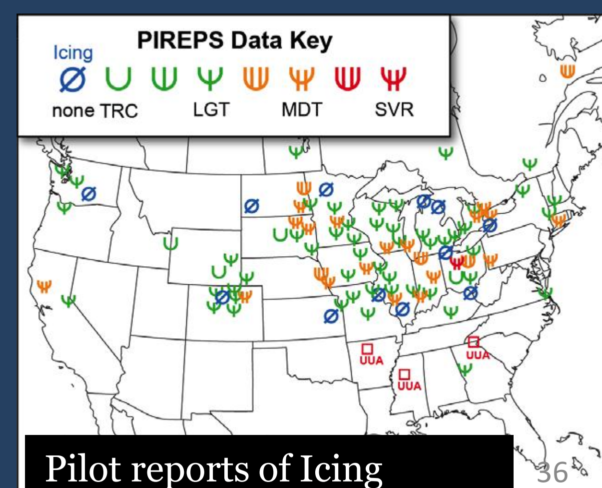






Pilot reports confirm the icing threat deduced from satellite data

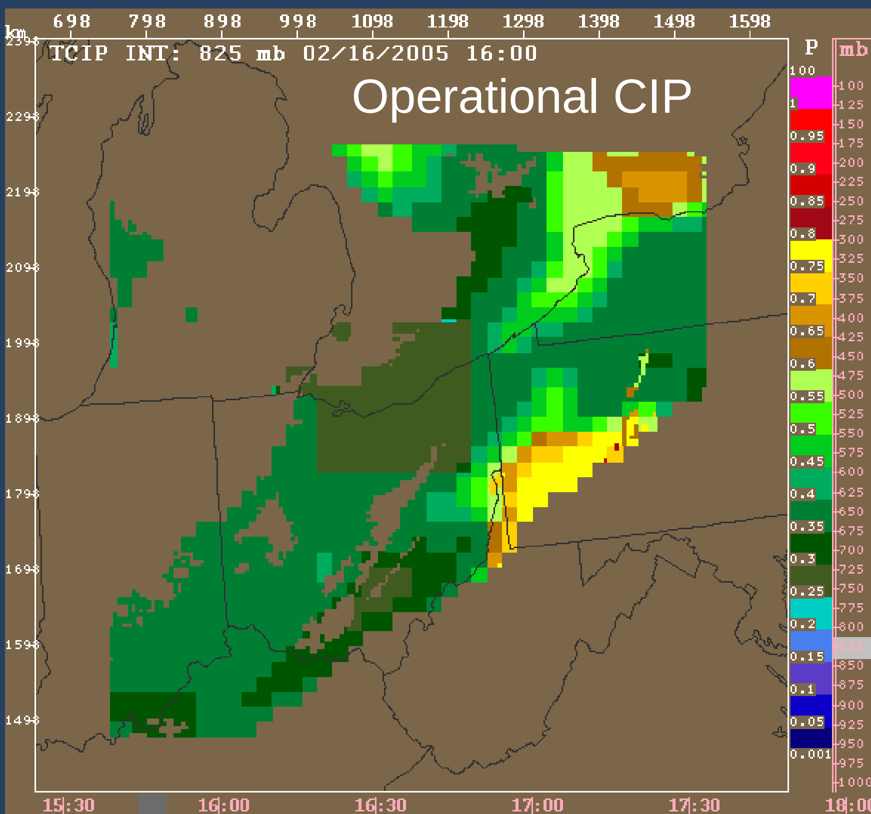
CTH and other parameters also help define vertical boundaries for icing conditions

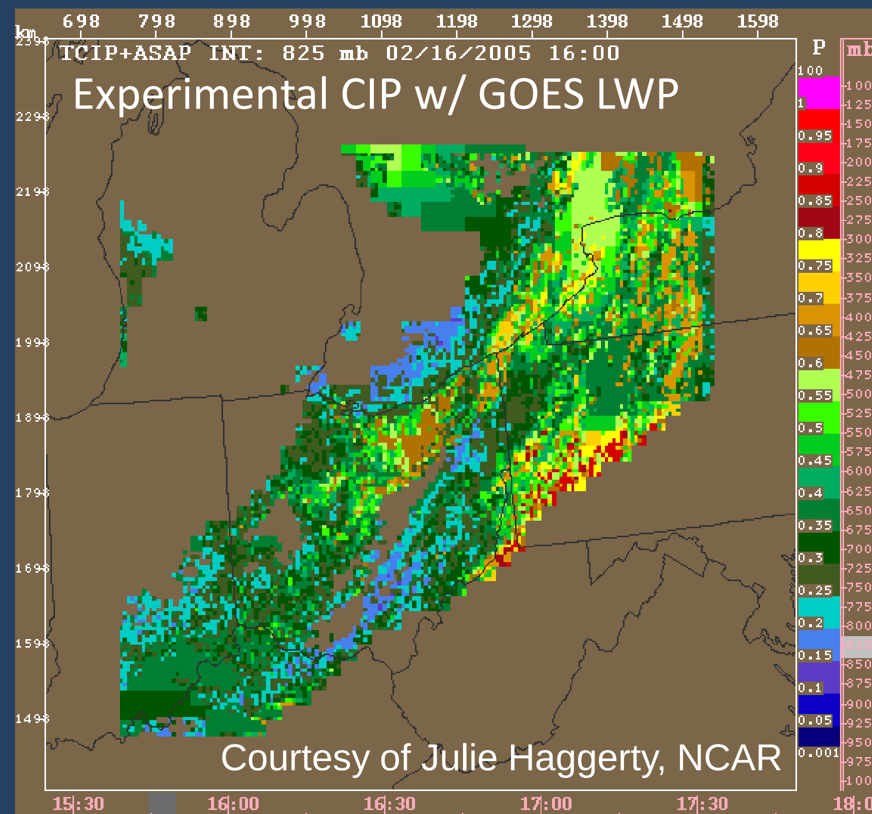


W. Smith Jr. NASA – See Poster #21

NCAR/FAA/NASA/NOAA Current Icing Potential (CIP)

- Operational version available at AWC uses satellite data in rudimentary way to locate clouds. Information on cloud microphysics are not used.
- Experiments testing the use of GOES LWP as an additional interest field in CIP have been conducted





- Inclusion of satellite-derived cloud microphysical parameters improves the CIP
- Better definition of the field gives more options to pilots!
- Results validated against research aircraft flights from NASA GRC

W. Smith Jr. NASA

Generation of AWG Cloud Products for Field Campaigns: Real-Time GOES-12/13 Cloud Products for TORERO

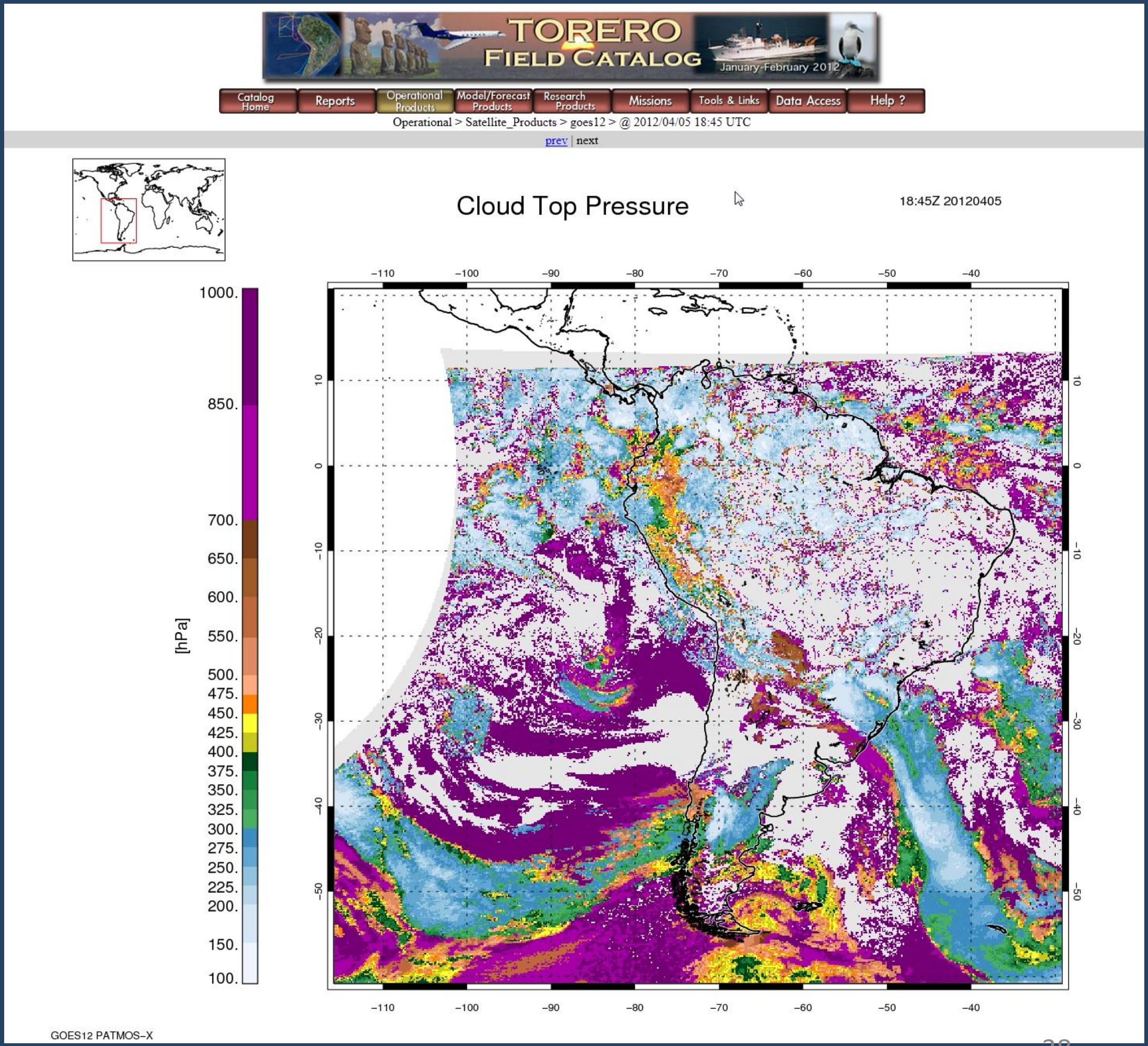
TORERO = Tropical Ocean tRoposphere Exchange of Reactive halogen species and Oxygenated VOC

TORERO was led by NCAR and and research flights flew from Central Chile and Costa Rica.

We provided GOES-12 and GOES-13 results every 15 minutes from December, 2011 to March 2012 to the Data Catalog.

Cloud Height information used in flight discussion/planning.

Validation with UW/SSEC HSRL data is planned as part of supplemental AWG product validation.



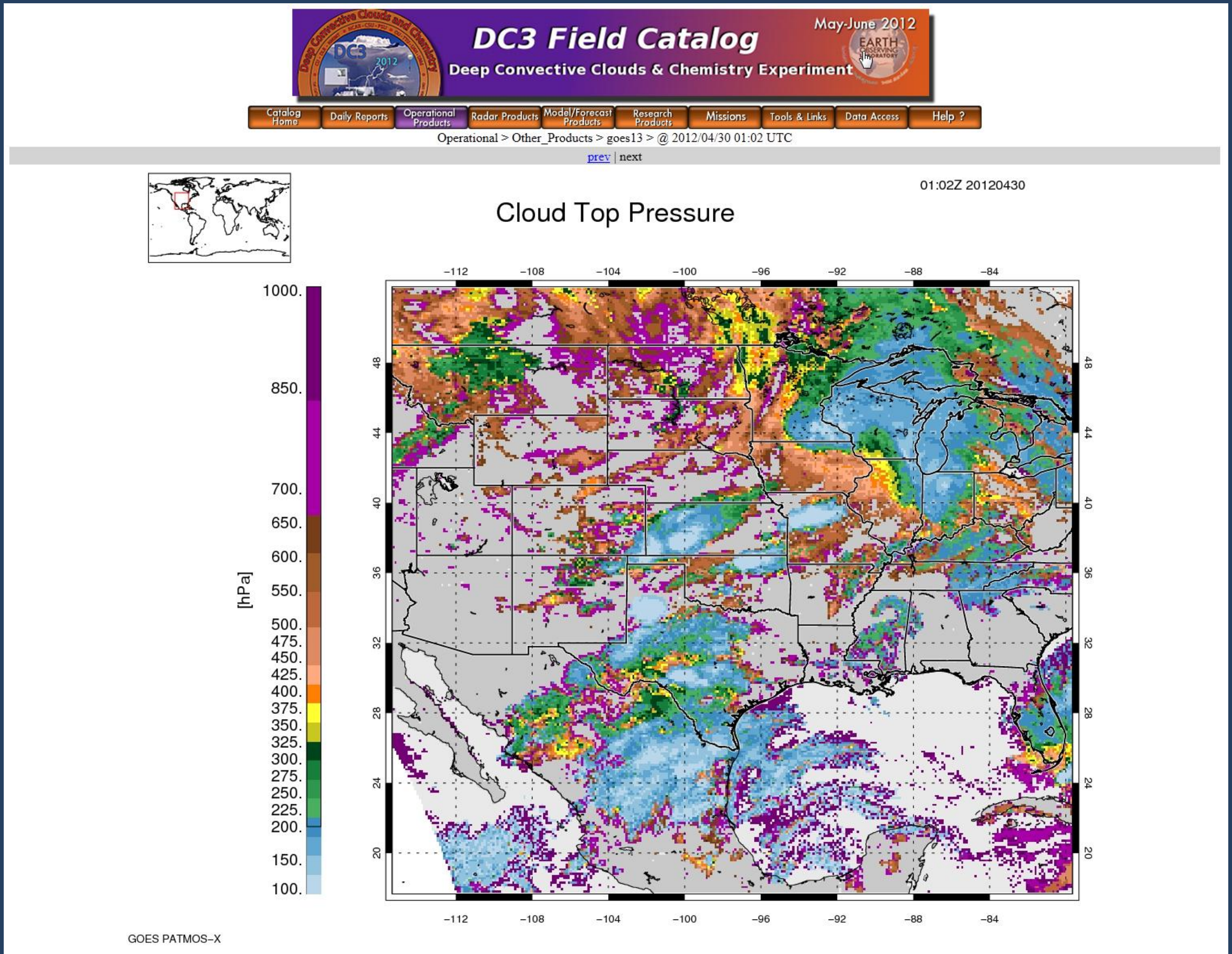
Generation of AWG Cloud Products for Field Campaigns: Real-Time GOES-13 Cloud Products for DC-3

DC3 = Deep Convective Clouds and Chemistry

Experiment period: May-July 2012

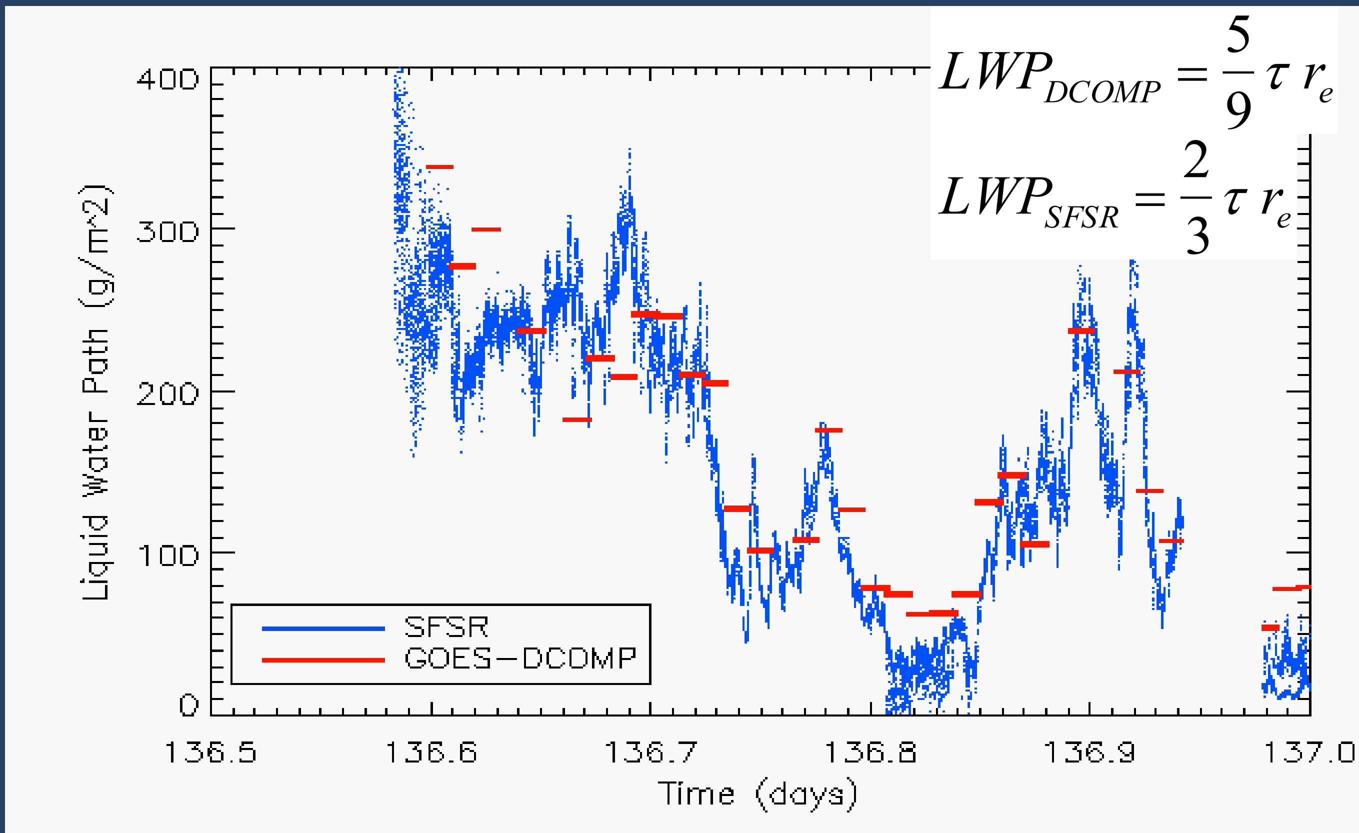
Data is being provided since April 27, 2012 from ASPB/CIMSS.

Validation with NASA Langley Dial/HSRL data and the University of Colorado SSFR (Solar Spectral Flux Radiometer) is also planned as part of supplemental AWG product validation.



Benefits of Field Campaigns – Access to New Sources of Validation

Example Validation Data from Field Campaigns: Comparison SFSR – DCOMP from GOES11

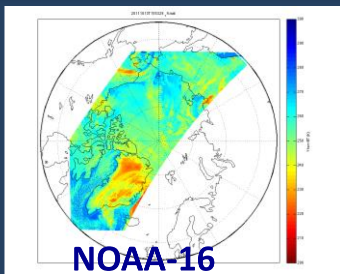


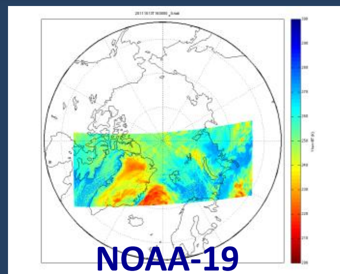
$$LWP_{DCOMP} = \frac{5}{9}\tau\, r_e$$

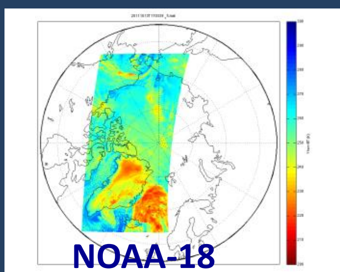
$$LWP_{SFSR} = \frac{2}{3}\tau\, r_e$$

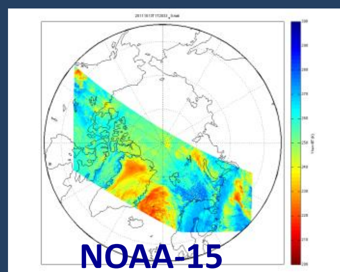
1. r_e from SFSR is representative for the whole cloud since its is a transmission measurement
2. r_e from GOES needs the adiabatic adjustment (0.833) since its from the cloud top

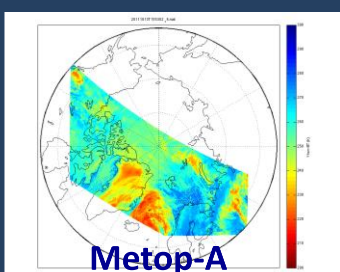
Morphing polar-orbiter imagery of cloud products for improved visualization and forecasting



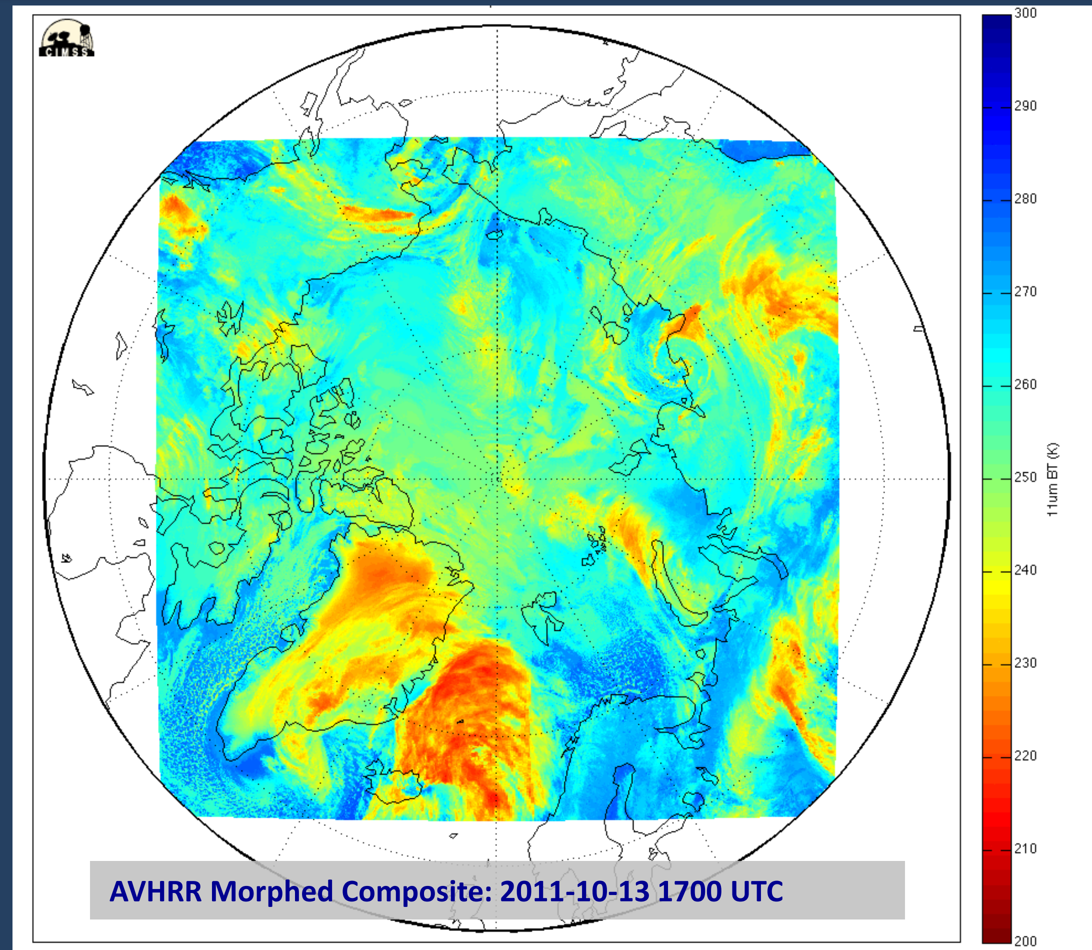








AVHRR
11μm Tb

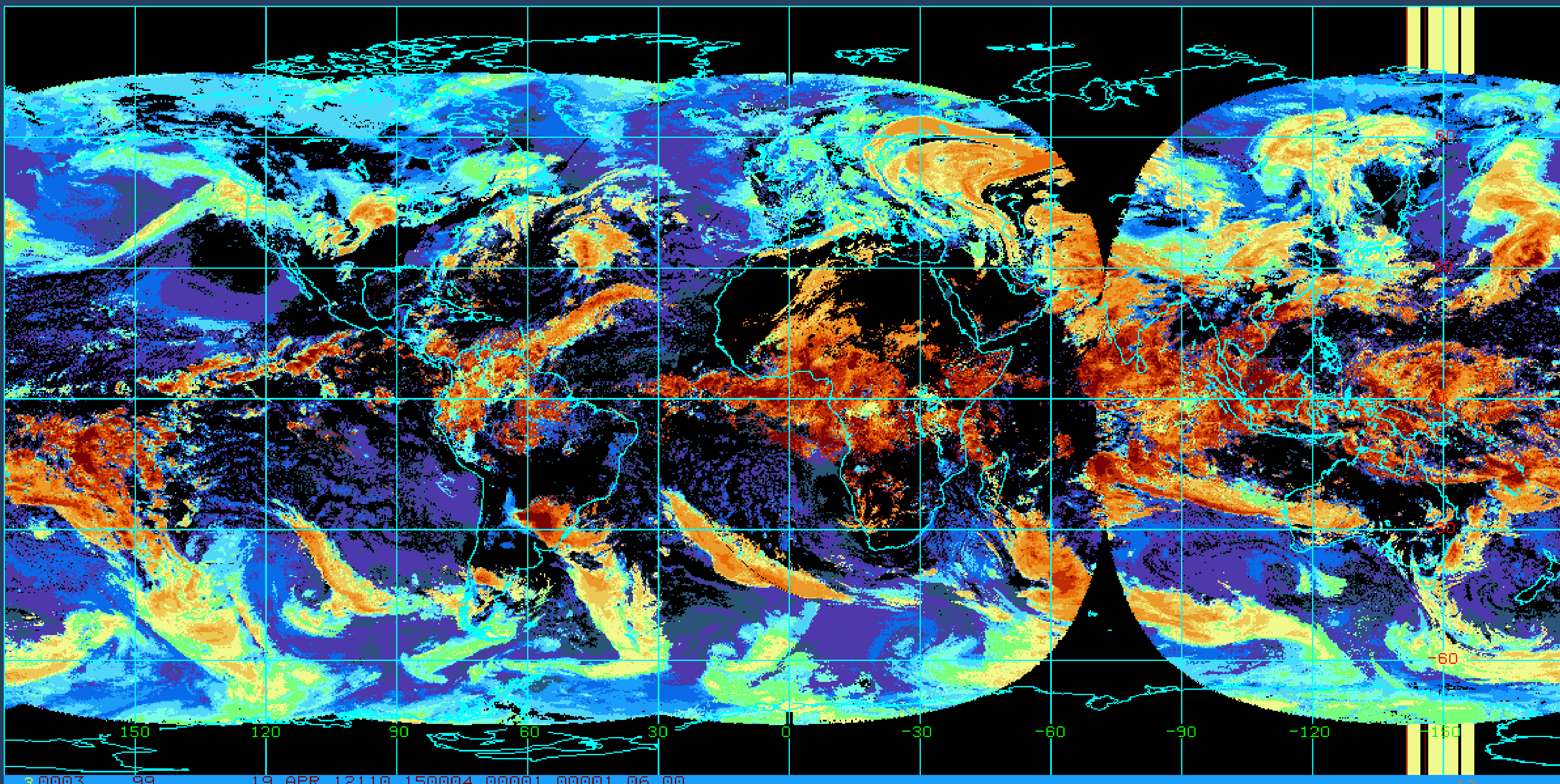


- Project Goal: Deliver near-seamless compositing of CLAVR-x and GSIP Cloud Product Composites over Alaska using "advective blending"
- Algorithm previously demonstrated with morphing of AVHRR 11um Tb in the larger polar region (above).
- Project time frame: June 2012 to January 2014

Tony Wimmers, CIMSS (see poster W-6)

Cloud Height Application: Global Analysis for Aviation

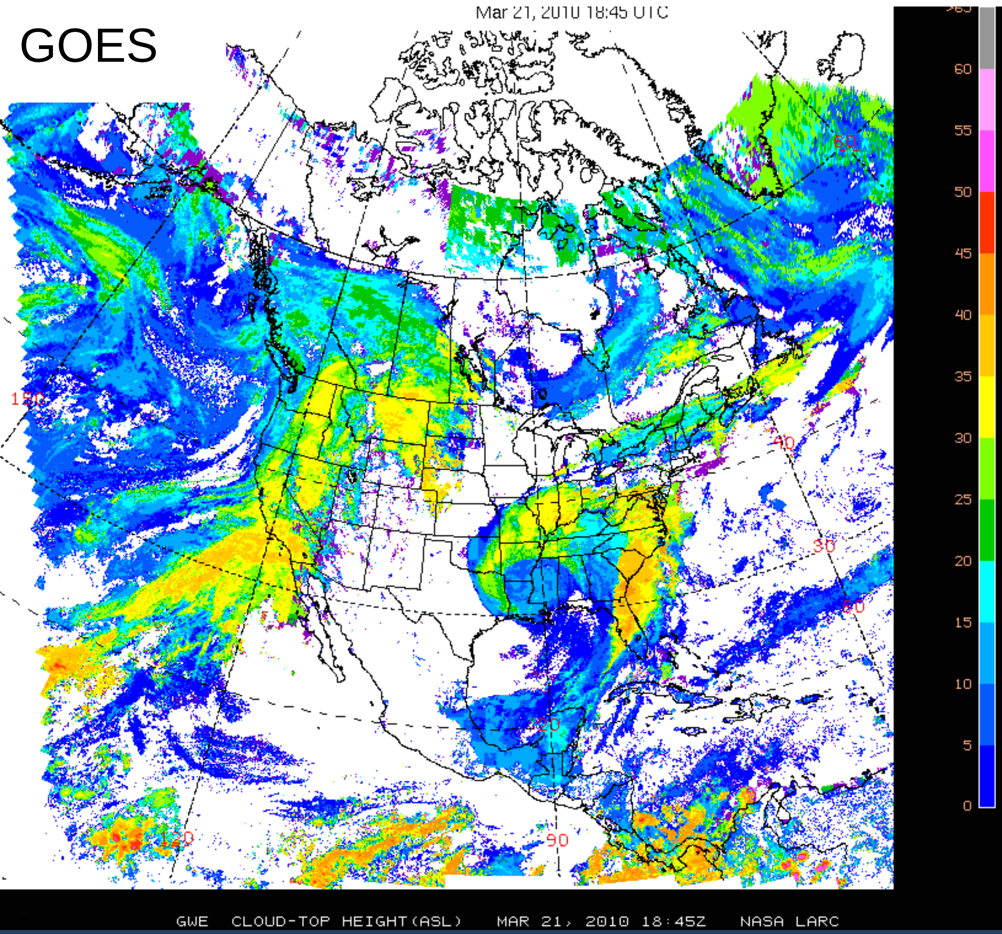
- CIMSS is making nearly-global geo-based cloud height fields from the AWG Cloud Height Algorithm (ACHA).
- The goal is to develop data for in-flight monitoring of cloud heights.

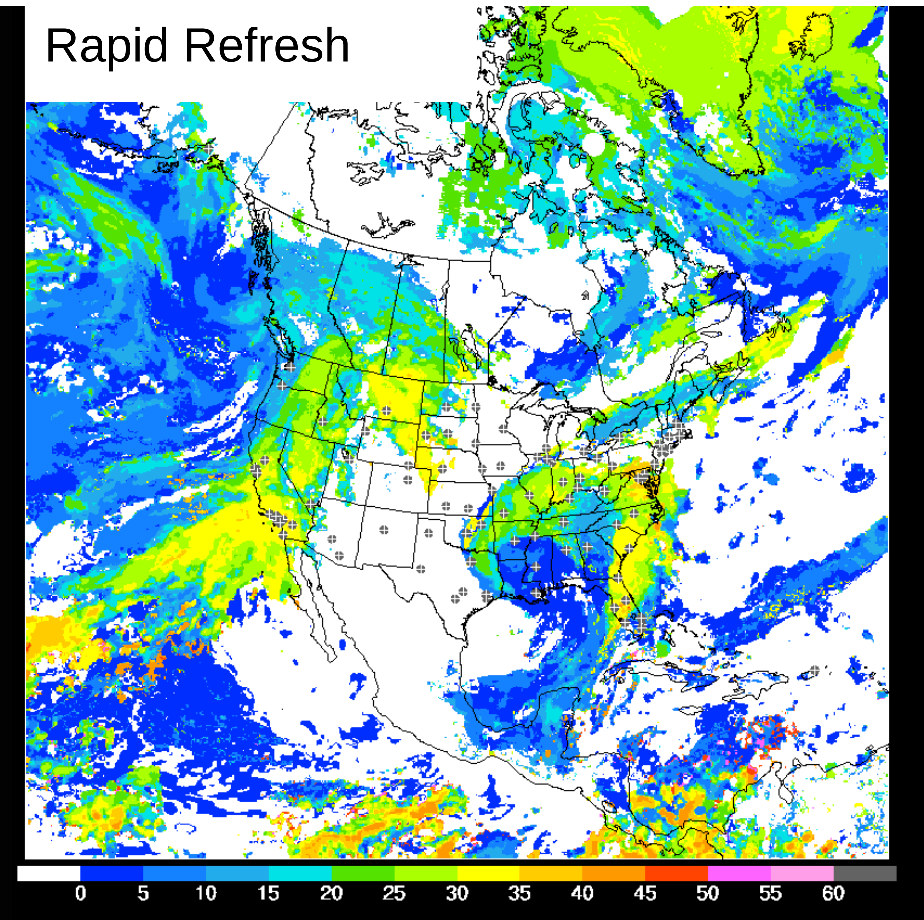


Jerrold Robaidek, SSEC/CIMSS

Satellite data assimilated into NOAA Rapid Refresh NWP produces more realistic clouds

Cloud-top Heights (Kft, AGL) 1845 UTC, 21 March 2010



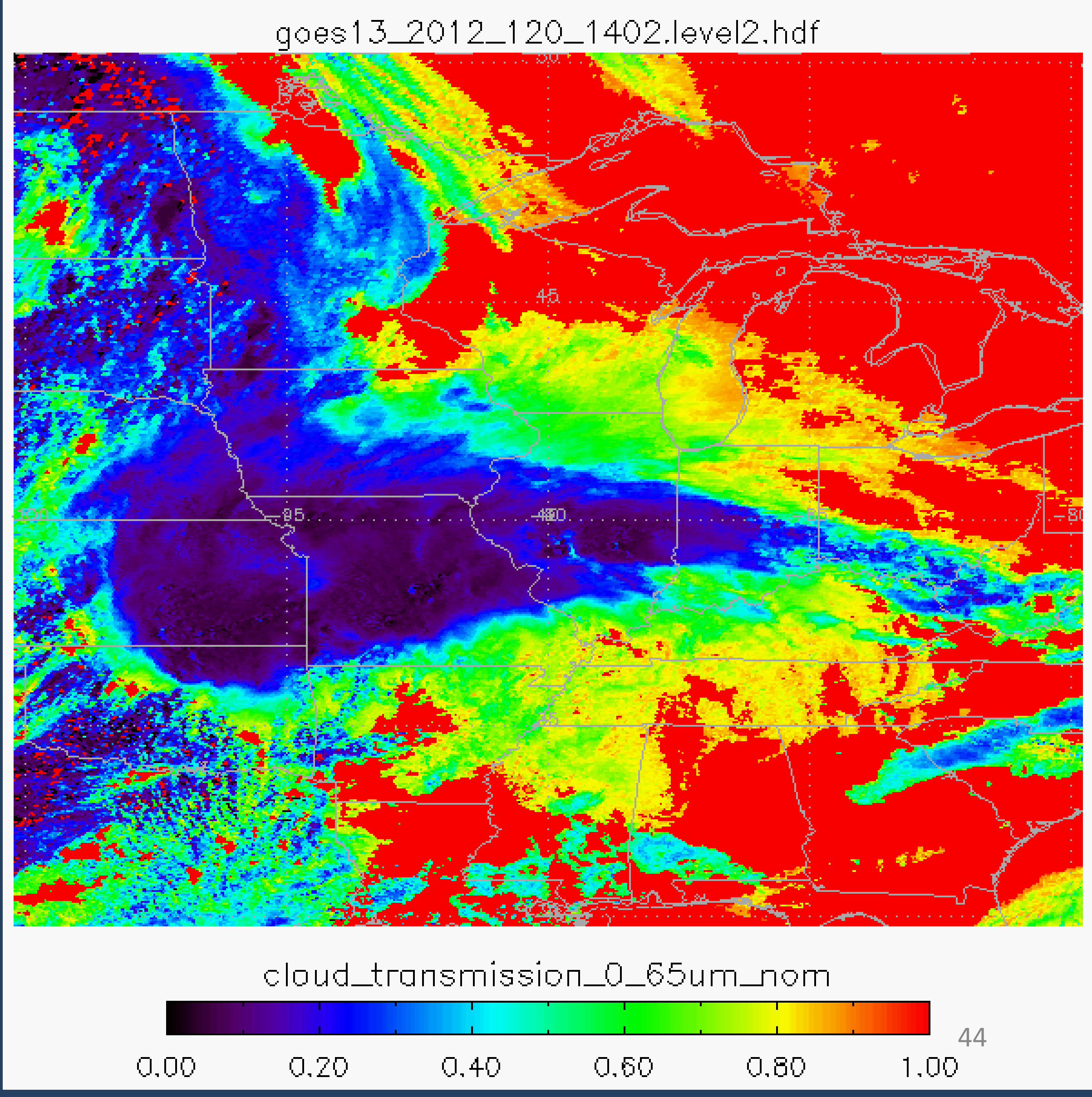


CTH assimilation started with GOES sounder data in the RUC and transitioned to GOES imager products over expanded domains.

W. Smith Jr. NASA

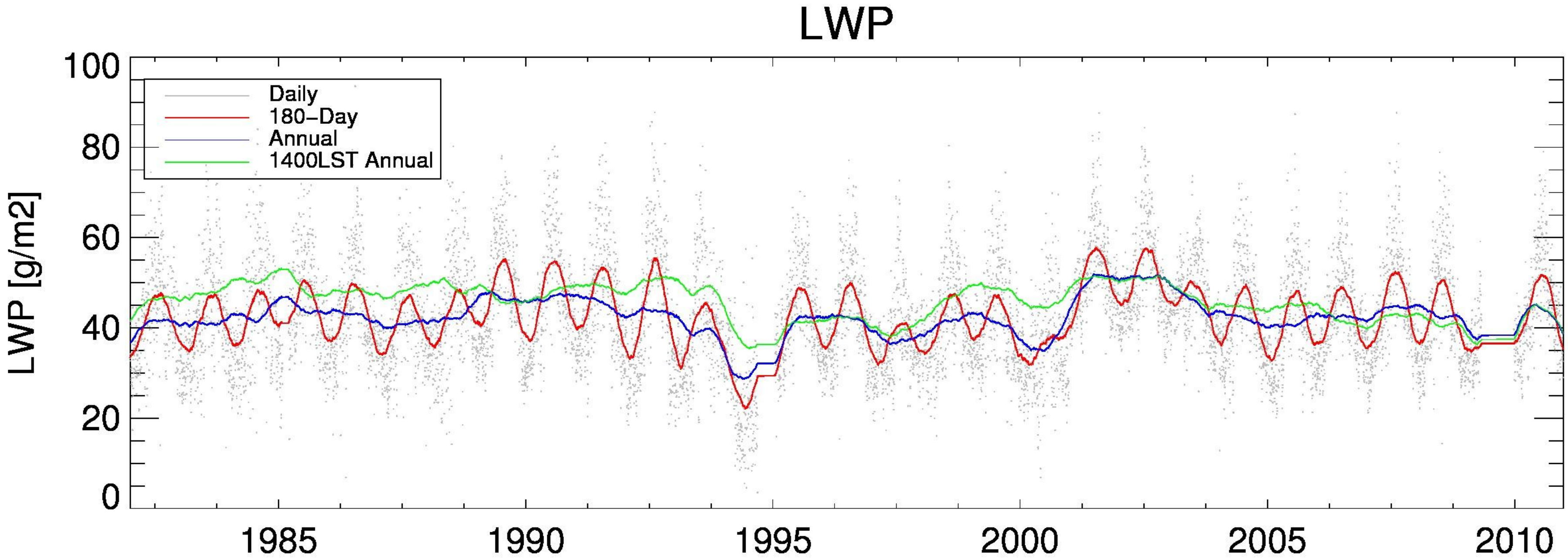
Solar Energy Applications

- AWG does generate a full suite energy budget projects.
- However, forecasting solar energy is mainly driven by forecasting the evolution of cloud properties (esp. optical depth).
- We generate cloud transmission with DCOMP in order to generate the required products. Cloud transmission is the main predictor of solar energy.
- We work with **Steve Miller (CIRA)** and **Manajit Sengupta (NREL)** on research in short-term (< 2hours) solar energy forecasts.
- We serve this data now to companies developing similar capabilities.



Climate Applications

- Most of the requests for cloud data we get are by climate users.
- The Pathfinder Atmospheres Extended (PATMOS-x) is a NESDIS cloud climatology based on POES/GOES imagers.
- Generating and serving climate data is beneficial since users are demanding.
- Analogs of AWG cloud algorithms are used for the AVHRR and GOES-Imagers.
- Image below is of cloud liquid water path from AWG DCOMP applied to AVHRR (1981-2011)



Conclusions

- The Cloud AWG Algorithms are progressing through the Sci2Ops process with Harris Inc.
- In the recent years, we have expanded beyond ABI and SEVIRI as an ABI proxy to include a full range of current sensors. These algorithms are running in real-time and serving many customers and applications.
- Through JPSS Risk Reduction, we'll apply our AWG algorithms to VIIRS within the STAR processing framework. Much progress has already occurred.
- Research is on-going to whittle away at the remaining algorithm issues and to open up new applications. We all seek additional collaborations in that regard.

JPSS VIIRS Cloud Mask Team Activities

JPSS Cloud Mask Team just completed 30-day tuning exercise. Tuning accomplished on selected "golden granules". Work done by CIMSS, AFWA and NGAS. Goal was to address major issues.

CIMSS role is to provide global analysis.

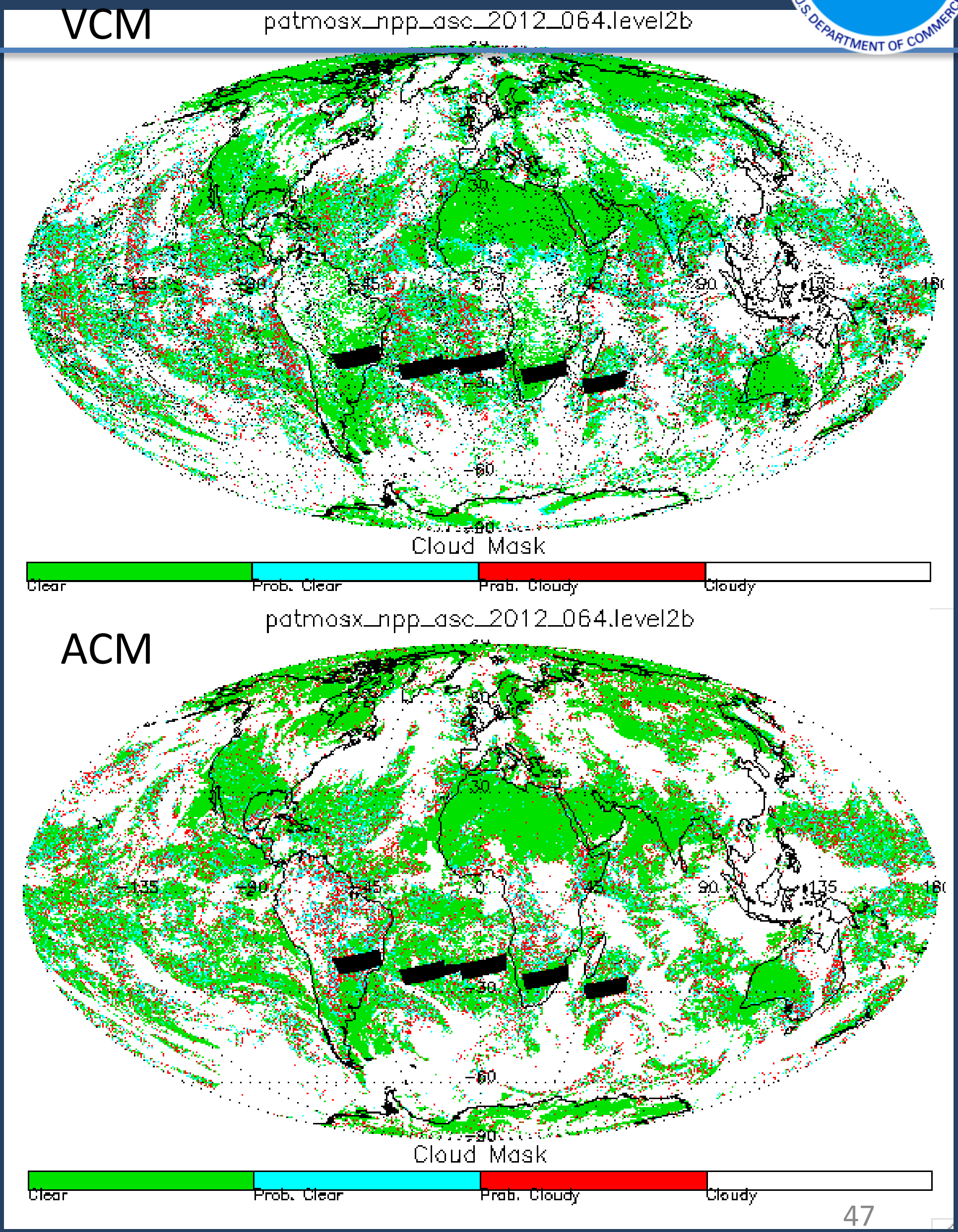
Probability of Correct Detection based on CALIPSO Analysis for One Day (March 4, 2012) of the binary masks is as follows:

VCM Pre-Tune = 92.6%
VCM Post Tune = 93.2%

Small improvement in POD but major artifacts mitigated.

With these improvements, VCM will go provisional.

We have also implemented the GOES-R AWG ABI Cloud Mask (ACM) on VIIRS to support the evaluation of the IDPS VCM and the JPSS RR.



The JPSS CAL/VAL Team – Cloud Status

- IDPS Cloud Mask just finished 30 day tuning led by Tom Kopp (Aerospace). Beta stage is coming later this month.

- IDPS Cloud Phase tuning will commence

- Through the UW/SSEC NPP PEATE (NASA funded), we have validated and analyzed many days of global VIIRS IDPS cloud products

- Some IDPS algorithms (cloud top height and cloud optical properties) have issues.

- These issues were discussed at last week's JPSS VIIRS CAL/VAL meeting.

- Team is trying to work with NGAS to pinpoint root causes of the IDPS algorithms.

VIIRS and GOES-R Cloud Mask Comparison

- VIIRS Cloud Mask (VCM) based on the NASA MODIS Atmosphere Science Team (MAST) Cloud Mask. Code was transferred in 2000.
- GOES-R AWG Cloud Mask (ACM) was based off the NESDIS Operational Mask (CLAVR-x/GSIP). Tests from MSG/SEVIRI community were added.
- ACM designed to allow users to select a subset of the tests and recompute the cloud mask. The MAST and VCM flags provide diagnostic information but do not allow one to turn off certain tests and regenerate a new mask.
- ACM specification is 88% Probability of Correct Detection for the Binary (yes/no) mask.
- VCM specification is tighter (i.e. 95% over ocean with 1% false and 4% missed) though probably-clear and probably-cloudy pixels are thrown out.
- See Poster W-18 for an ACM / VCM comparison.