Advances in Cloud Satellite Cloud Retrievals for ARM

Patrick Minnis, W. L. Smith, Jr., D. R. Doelling
NASA Langley Research Center, Hampton, VA

R. F. Arduini, J. K. Ayers, M. M. Khaiyer, R. Palikonda, D. A. Spangenberg, Y. Yi, C. R. Yost
SSAI, Hampton, VA

P. W. Heck
CIMSS, Univ. Wisconsin, Madison, WI

F.-L. Chang
National Institute for Aerospace

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Objectives

• Develop cloud and radiative flux retrieval algorithms and satellite-based cloud property datasets for use in ARM's characterizations of clouds and radiation over **all domains**

- construct an approximate 4-D field of cloud hydrometeors

- know horizontal footprints, vertical boundaries val w/ ARM data

- produce accurate cloud microphysical properties

- validate with ARM, in situ, & other satellite data

- provide best estimates of TOA fluxes & surface radiation

- validate with ARM & other satellite data

- make all products easily accessible to ARM researchers

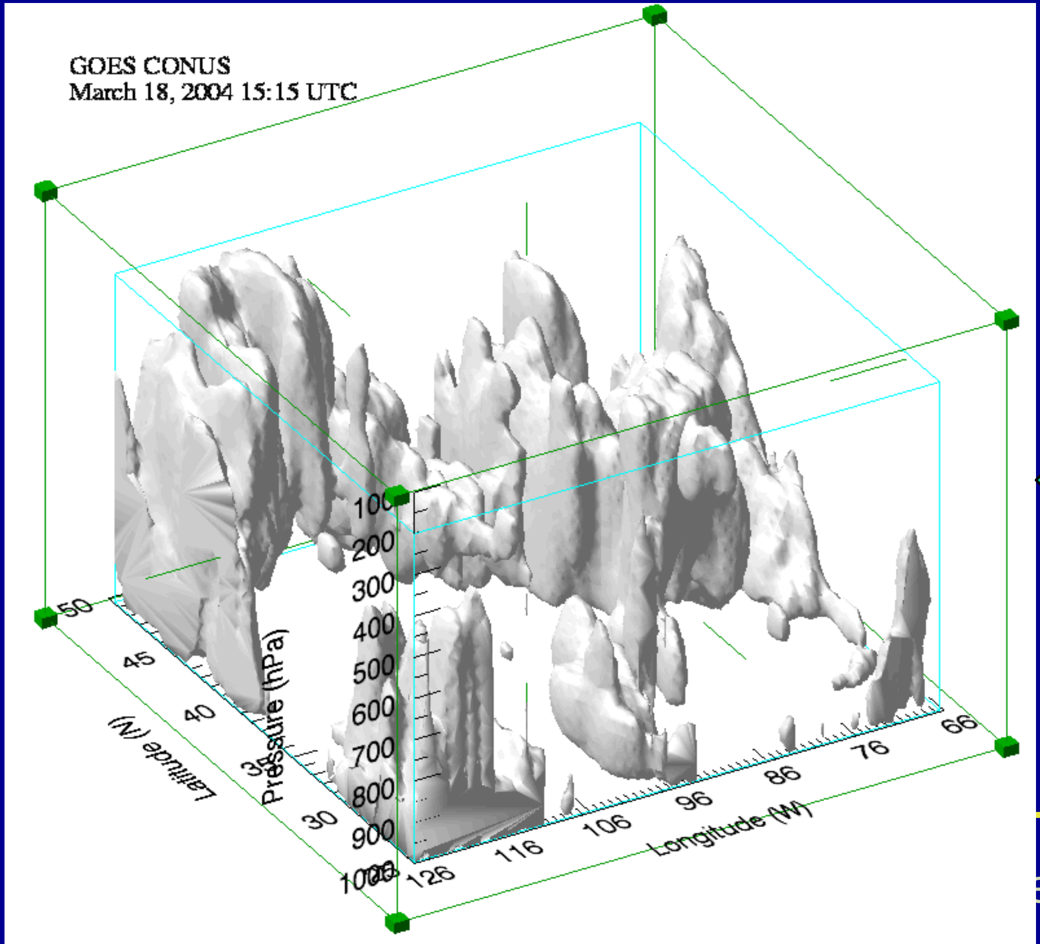
- interactive web sites

- ARM archive

4-D Approximation

- Geostationary satellite data necessary to quantify the evolution of a given cloud system – provides time element

- Algorithms & parameterizations used to convert a few spectral radiances into the 3 spatial dimensions



2-D Cloud Retrieval Maps From GOES Have a 3rd Dimension: Cloud Thickness

We want a better version of this!

Efforts toward better 3-D cloud fields

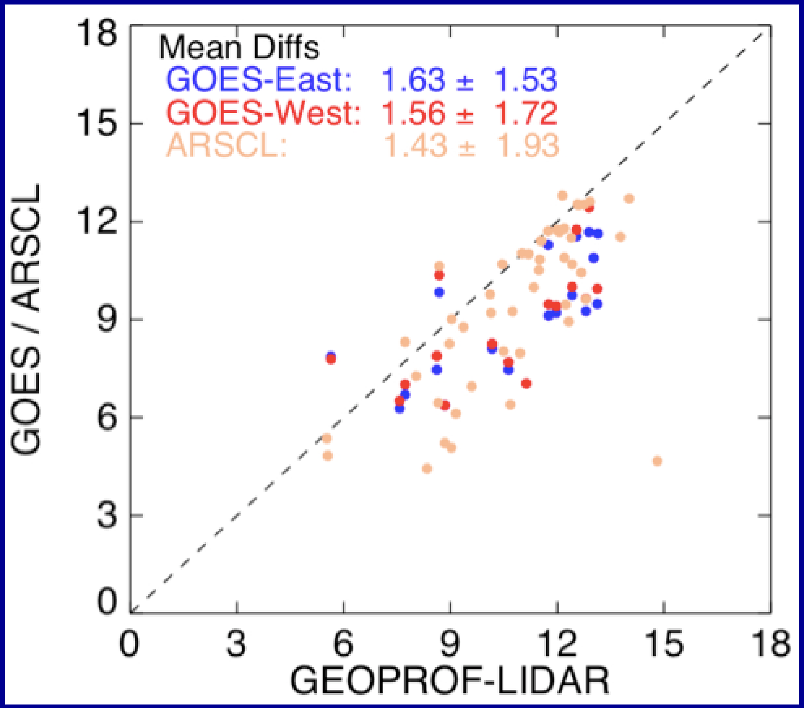
- New variable lapse rates for low-level cloud placement
  - *based on CALIPSO-MODIS matched data*
- Deep cloud top height correction
  - *based on CALIPSO-MODIS matched data*
- New cloud thickness parameterizations
  - *based on CloudSat-MODIS matched data*
- Improved detection of small clouds
  - *cumulus fields detected using hi-res data*
- Multi-layer cloud detection and retrieval
  - *thin cirrus over low clouds*
- IWC/LWC vertical profiles
  - *based on stats from CloudSat*
- Merging surface & satellite data to improve cloud base estimates

All of these algorithms will be verified independently using ARM data

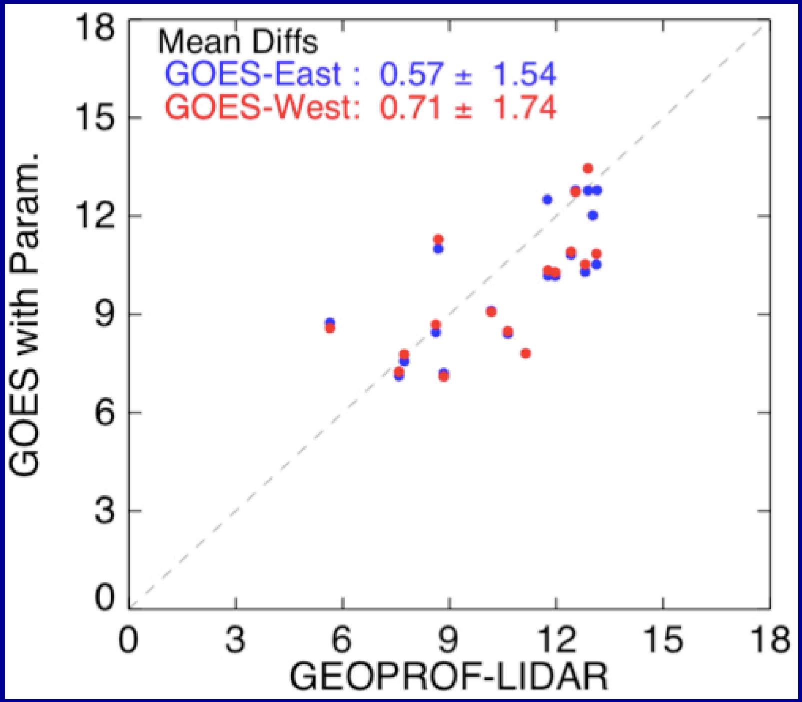
Improved optically thick cloud top heights

For optically thick ice clouds, satellite IR temperature and MMCR underestimate physical cloud top by 1-2 km---

Ztop = T(z)



Ztop = T(z) + Δz(VZA)

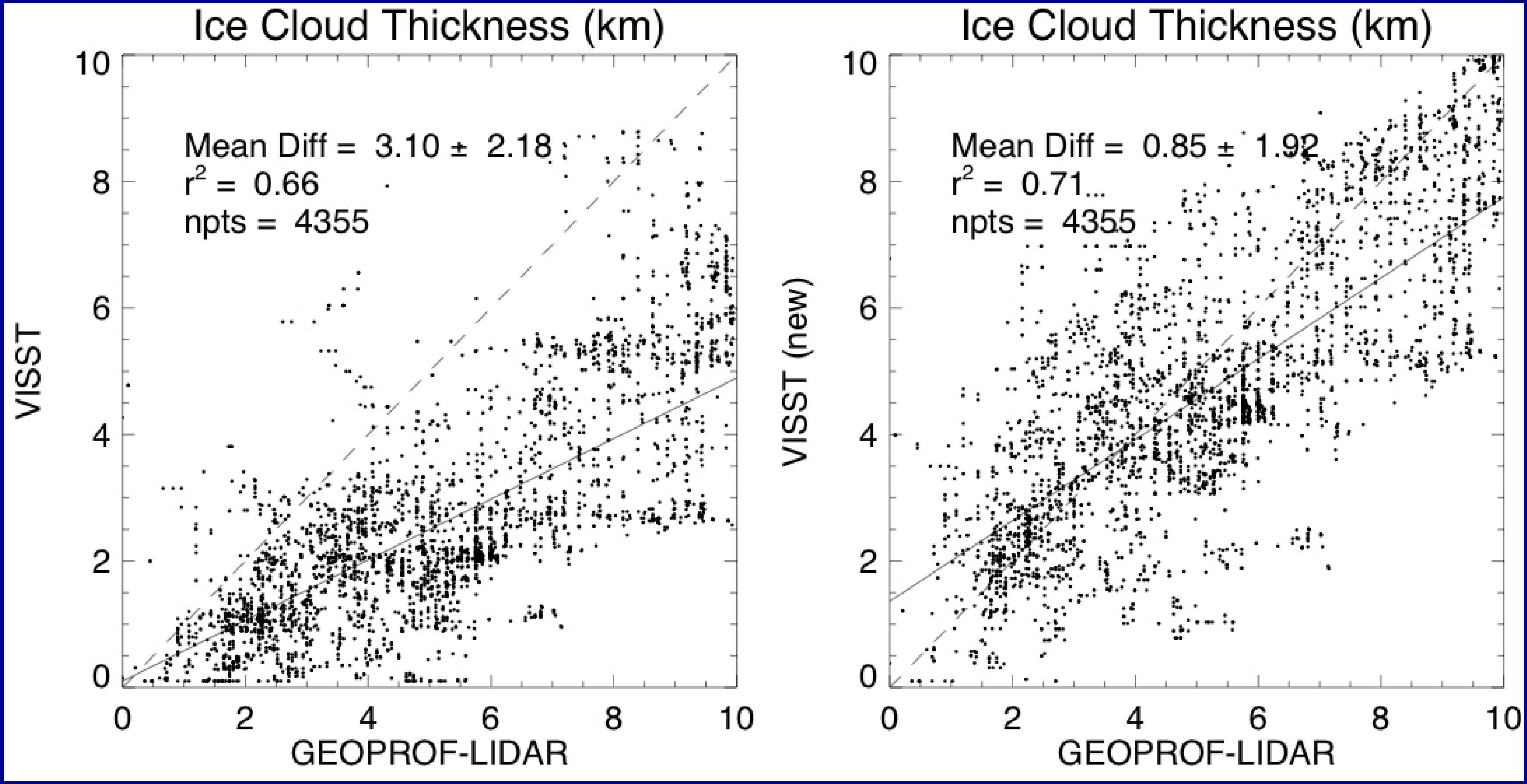


Parameterization developed using matched CALIPSO and satellite IR top heights gives much smaller biases in cloud-top height--- used in all retrievals

Yost poster

New cloud thickness parameterizations

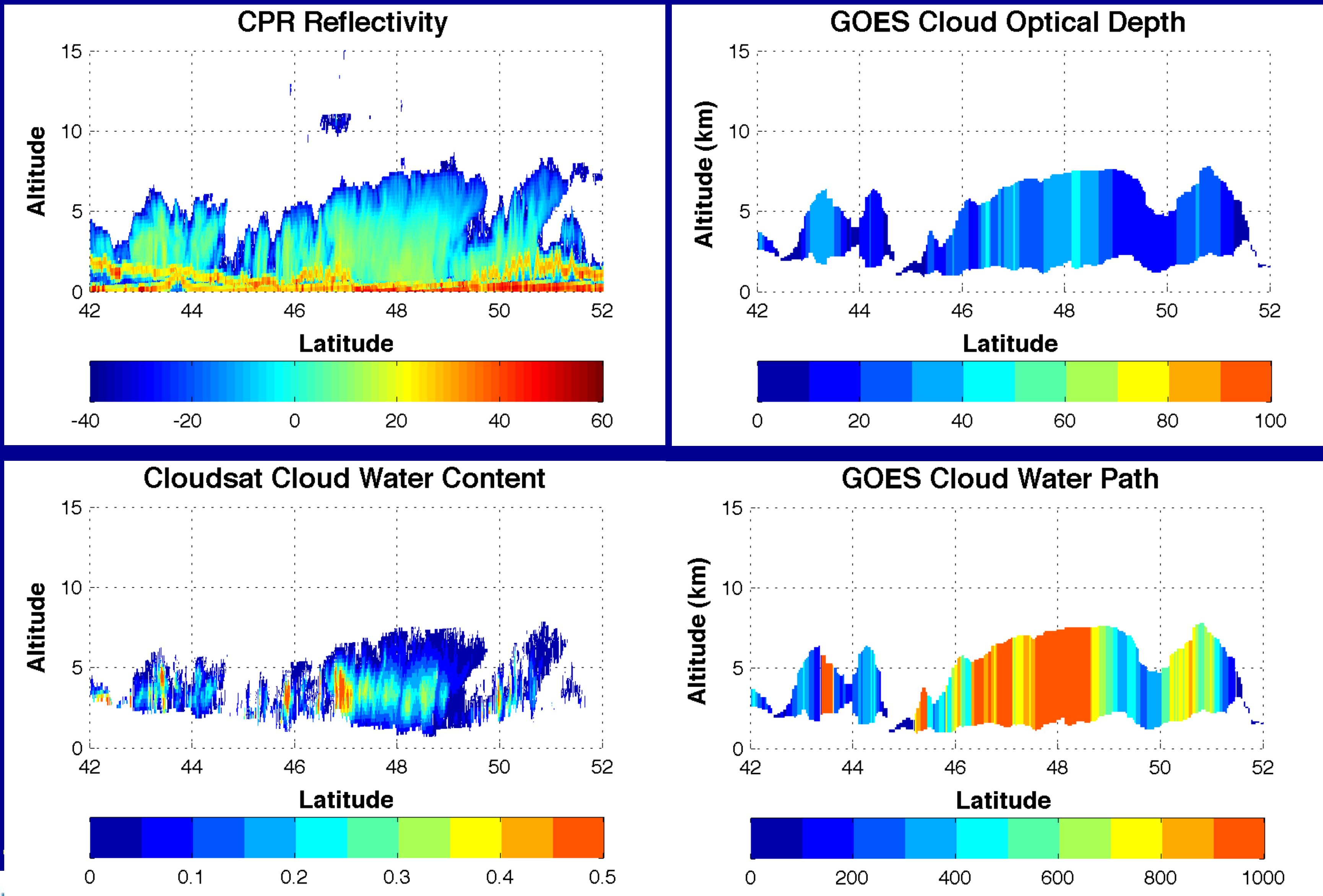
Older parameterizations based on field experiment and SGP data; newly developed models based on CALIPSO-CloudSat global statistics



Parameterization yields better thickness estimates but needs more work and validation at each ARM site --- parameterization based on 1330 LT orbit data

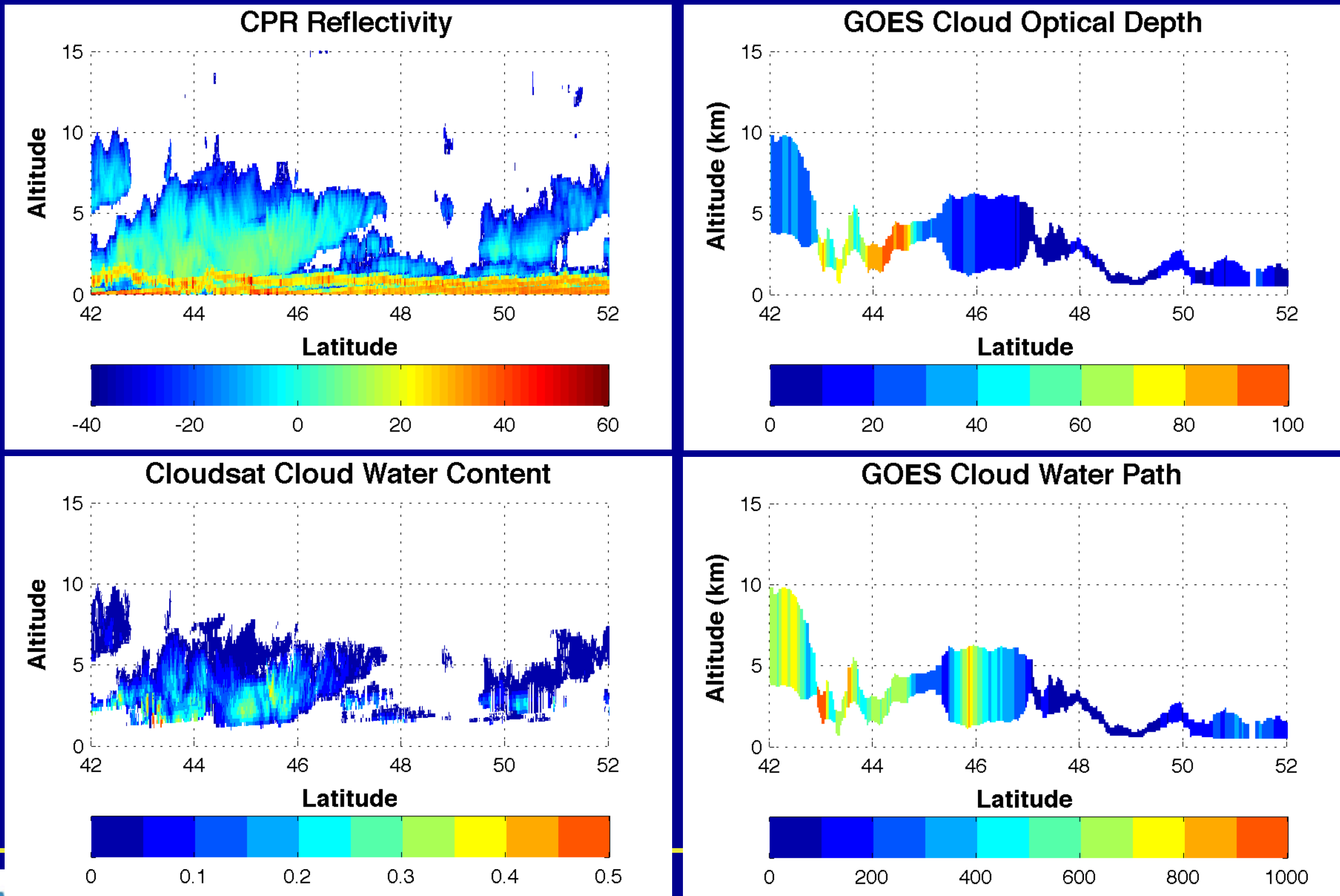
Providing WC profiles requires stats from GOES-CloudSat comparisons

March 28, 2008 (~2110 UTC overpass; 42-52 N)



Some GOES-CloudSat comparisons better than others…

March 28, 2008 (~1745 UTC overpass; 42-52 N)



Retrieval Enhancements

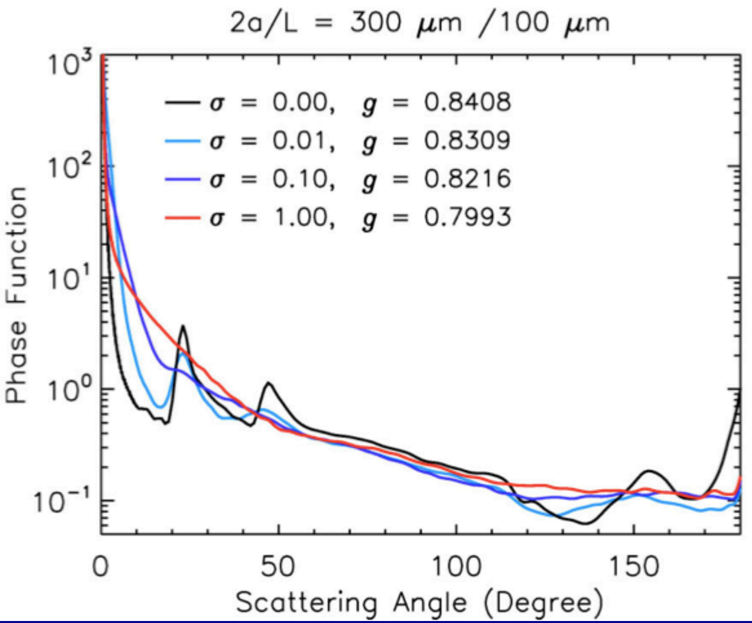
- Evaluation of new ice crystal reflectance models
  - *improve retrievals of τ and cloud height Ze*
- Combining CO_2-slicing with VIS-IR retrievals
  - *force match of cirrus Ze and τ by adjusting **g***
- Use alternate (IR-based) methods to retrieve cloud properties over snow when spectrally limited (GOES, AVHRR)
  - *current results yield no retrieval or large τ*
  - *also examine mixed phase detection*
- Develop empirical corrections for scattering angle dependencies of water cloud microphysical properties
  - *use ARM surface retrievals as reference*
- Determine limits of nighttime IR retirevals
  - *3.7-µm channel contains information past $\tau = 4$*

All of these algorithms will be verified independently using ARM data

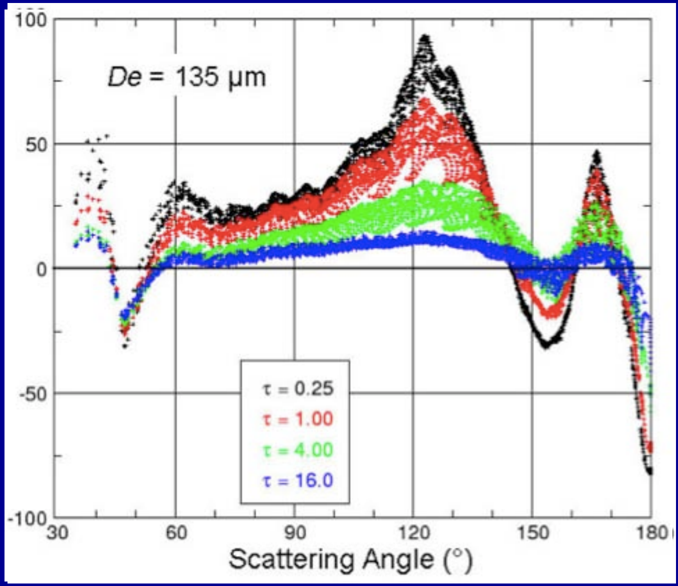
Testing New Ice Crystal Models

Hexagonal column models tend to overestimate τ
- rough or enbubbled xtals have larger asymmetry factors
  => smaller τ on average

Phase functions for various degrees of surface roughness, σ
$\lambda = 0.65$ μm



Reflectance difference (%) for smooth-rough xtals
$\sigma = 0.5$



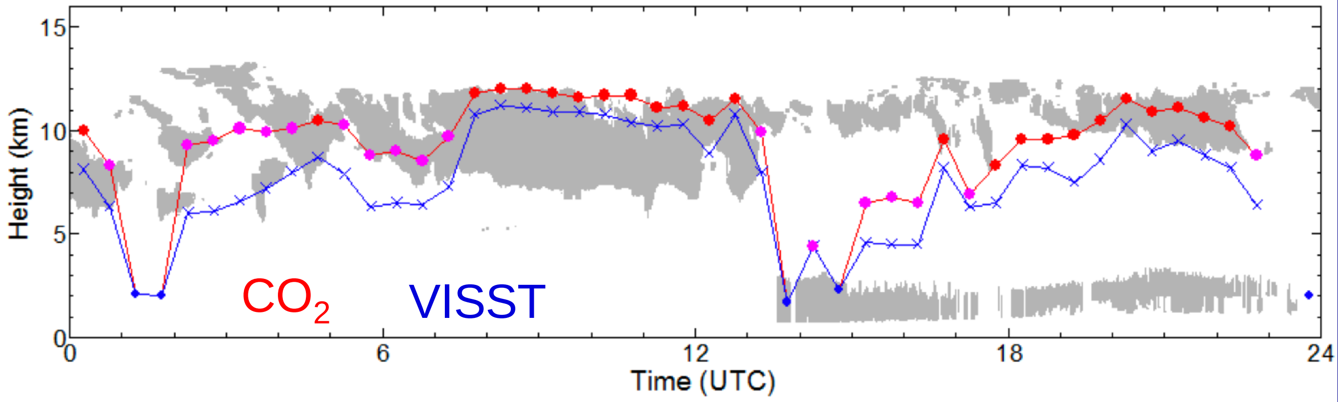
Minnis poster

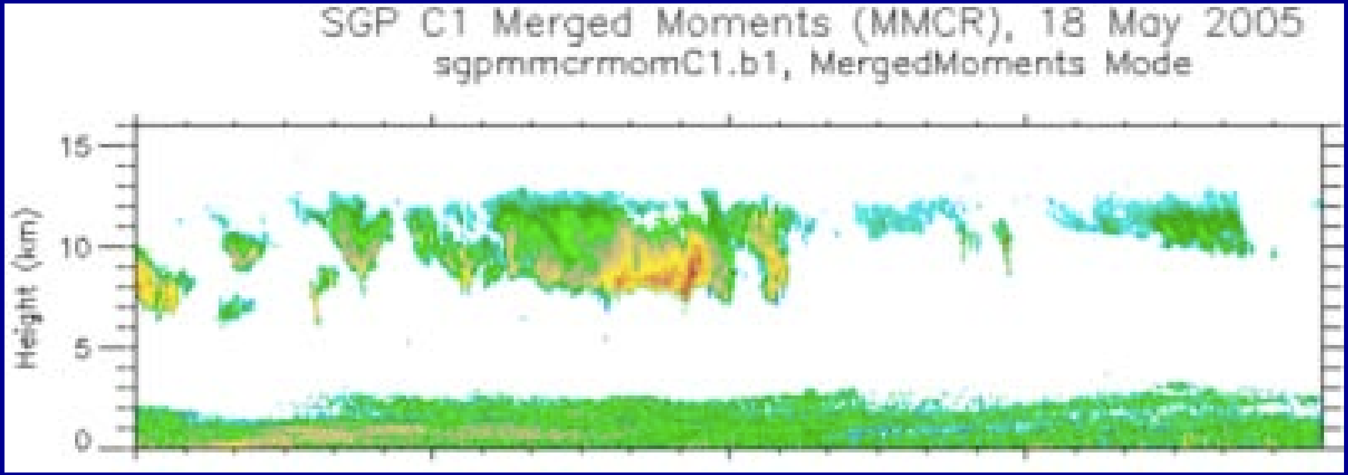
Cloud Top Height Retrievals Using 2-chan CO_2 Method

CO_2 method yields more accurate values of Ze in many cases

CO_2 method being combined with VISST to get better τ perform multilayer cloud detection & retrieval

GOES-12 Ze vs ARSCL, 18 May 2005

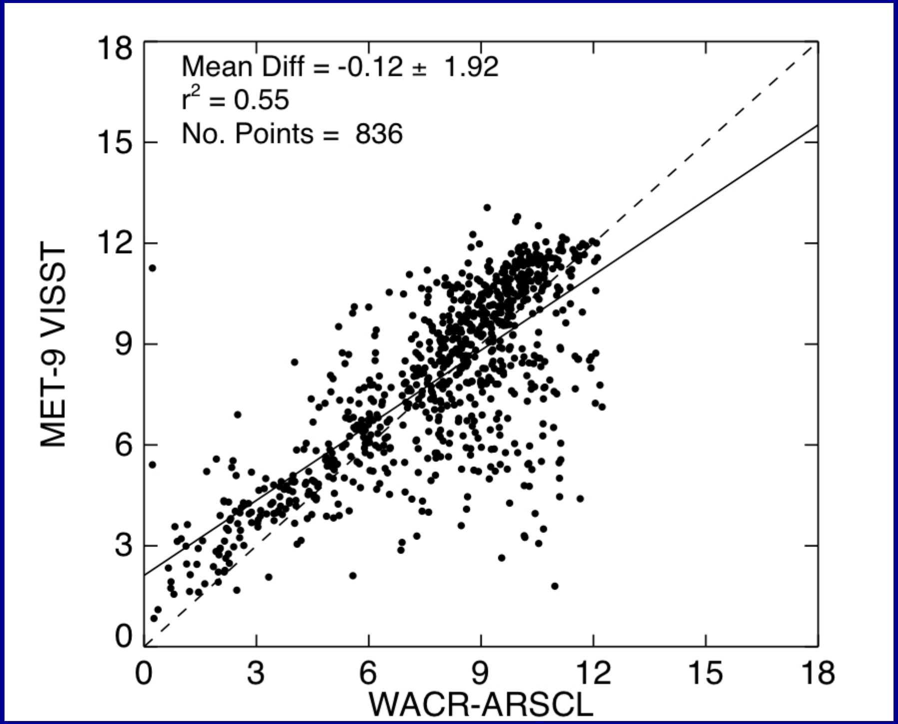




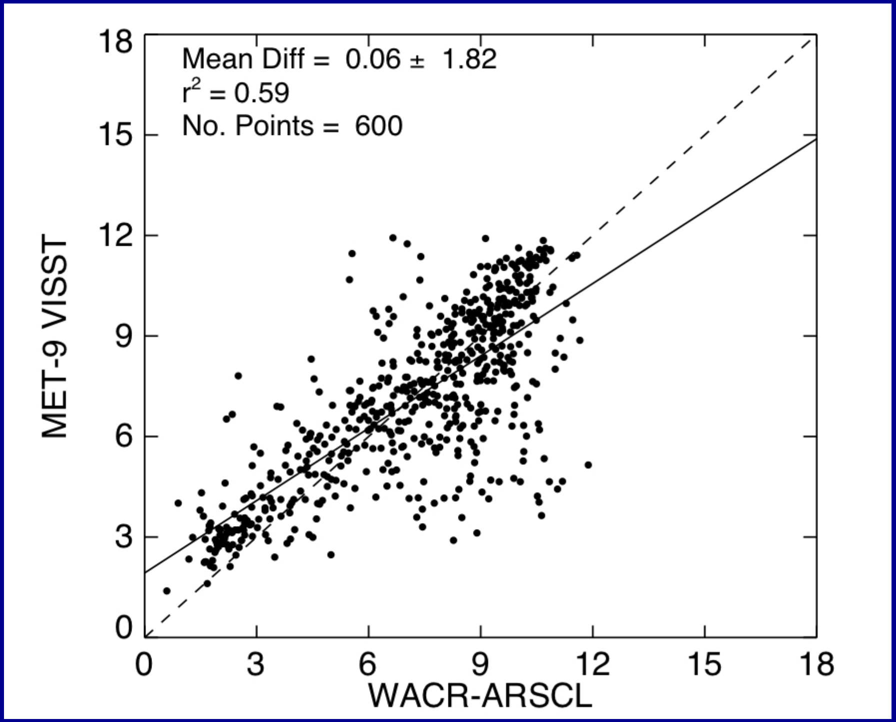
Cloud Top Heights From Combined VISST-CO_2 Method

Black Forest site, Summer 2007

All Clouds - Night



All Clouds - Day

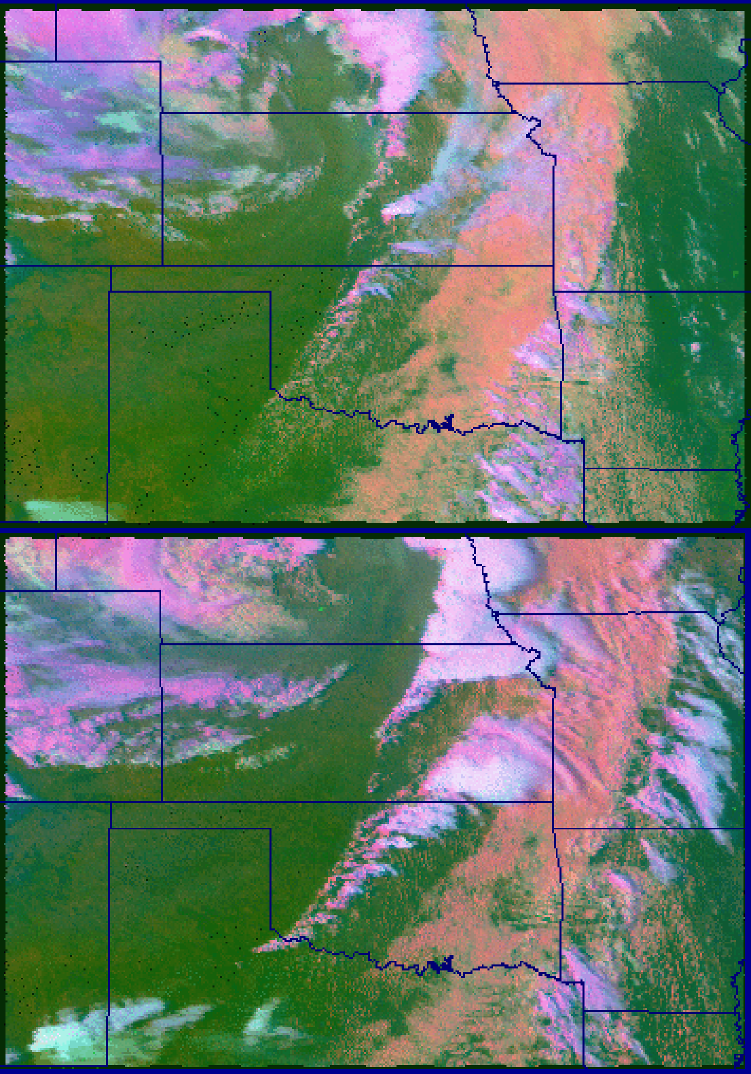


Except for some low cloud overestimates & multilayer cloud underestimates, the combined method yields nearly unbiased results compared to ARM ARSCL data over Germany

Ayers poster

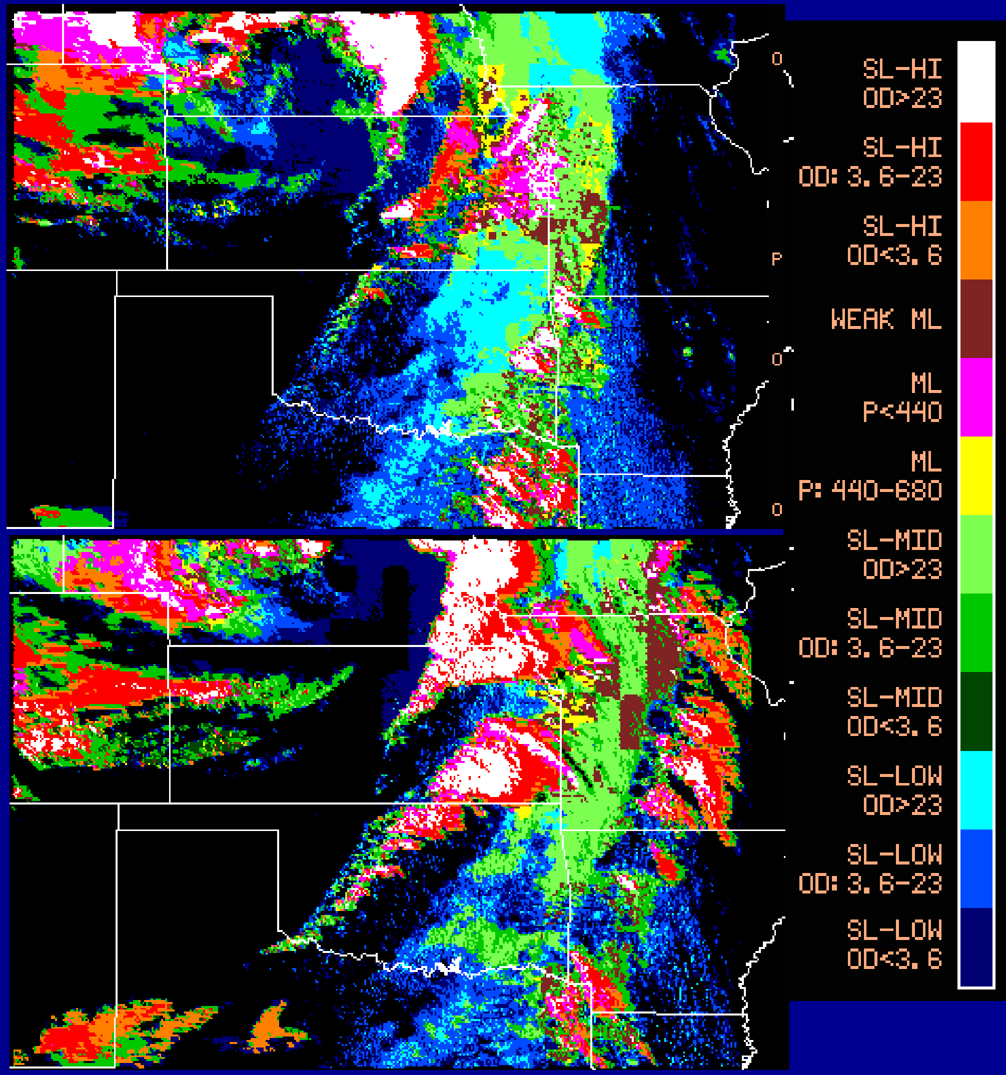
Multi-layer Cloud Detection & Retrieval VISST + CO_2 Method

GOES-12, 23 March 2009

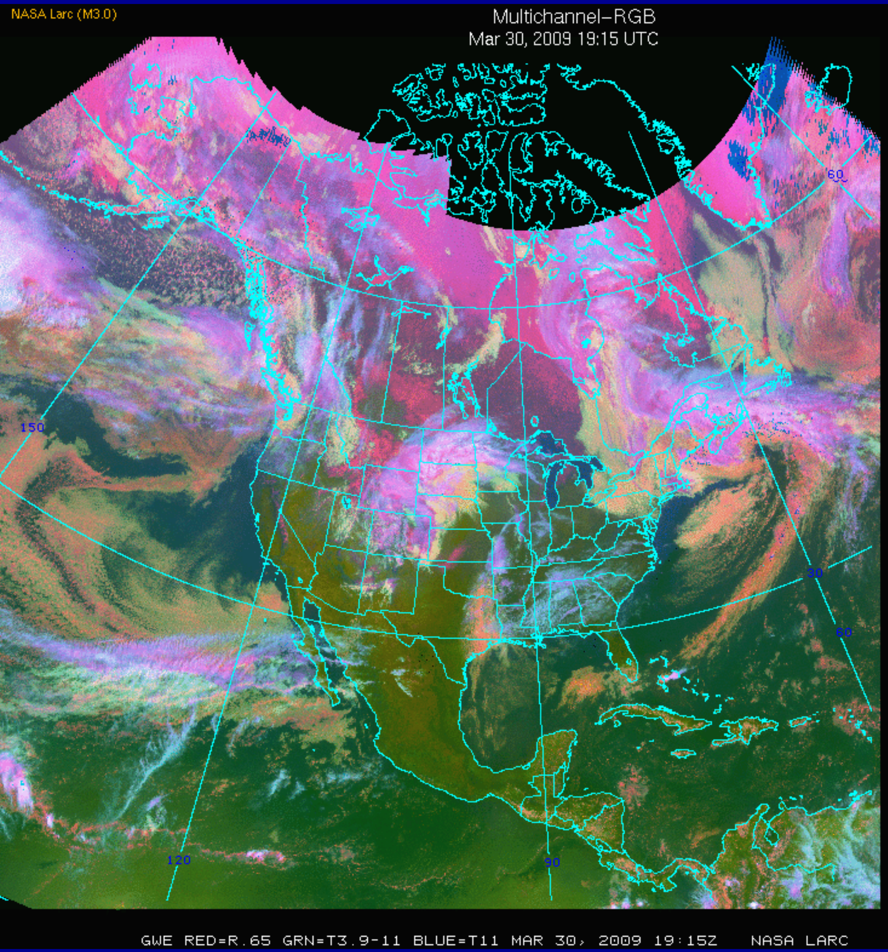


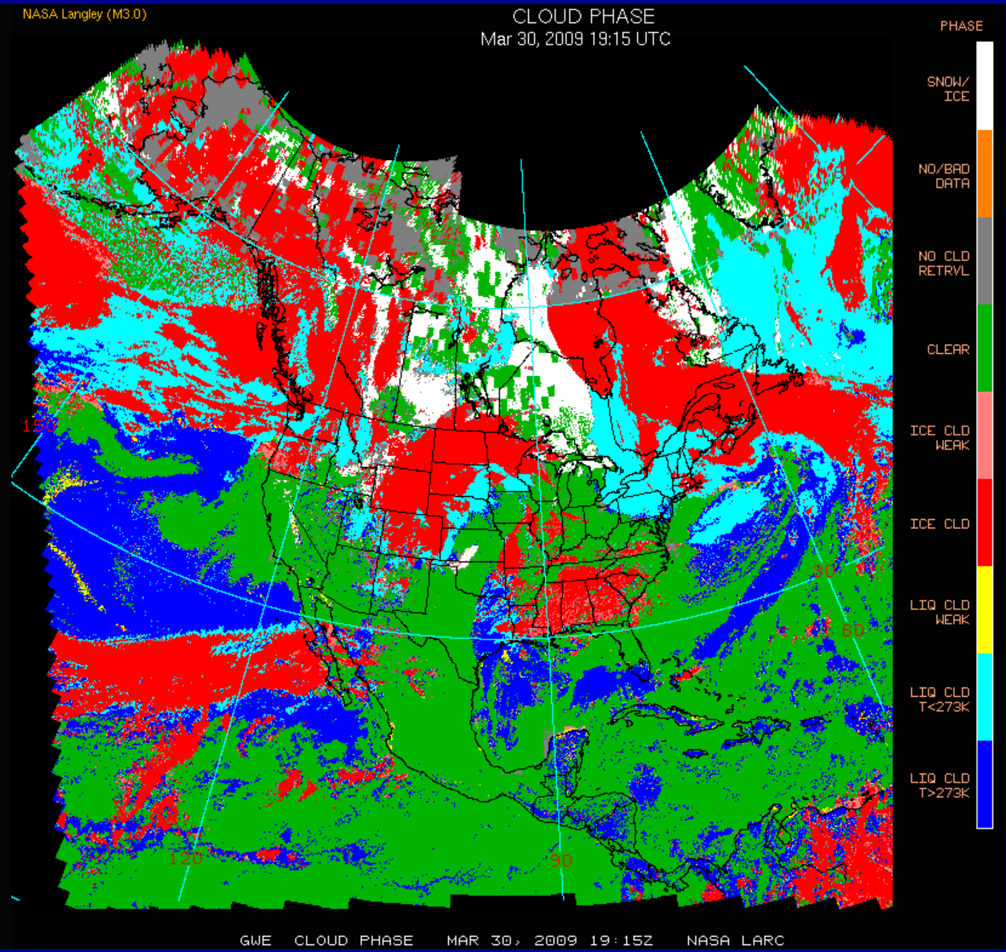
1945 UTC

2215 UTC



New Rapid Refresh Near-Real Time Domain





New domain includes Alaska, albeit at high viewing angle – many no retrievals and large τ over snow (not shown)

Radiation Improvements

- Better TOA narrowband-to-broadband conversion formulae

SW *- seasonal & domain specific fits*
- better representation of SZA dependence

LW *- seasonal & domain specific fits*
- improved cold end terms

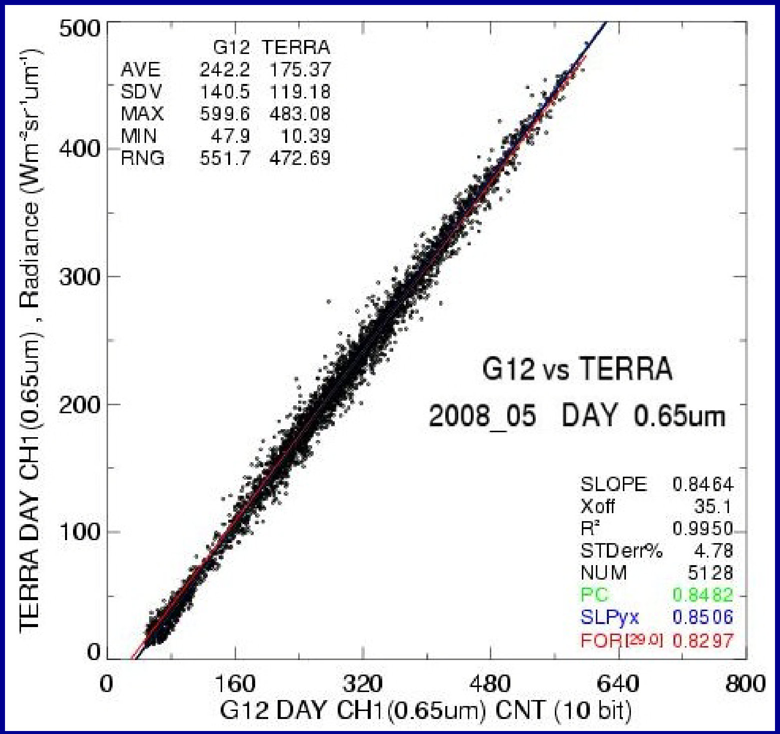
- Surface skin temperature (0.5° grid) for clear areas
- Surface radiation fluxes (later this year, 0.5° grid)
- Continuing satellite calibration

- normalizing all imagers to MODIS
- more reliable inter-satellite cloud properties& fluxes

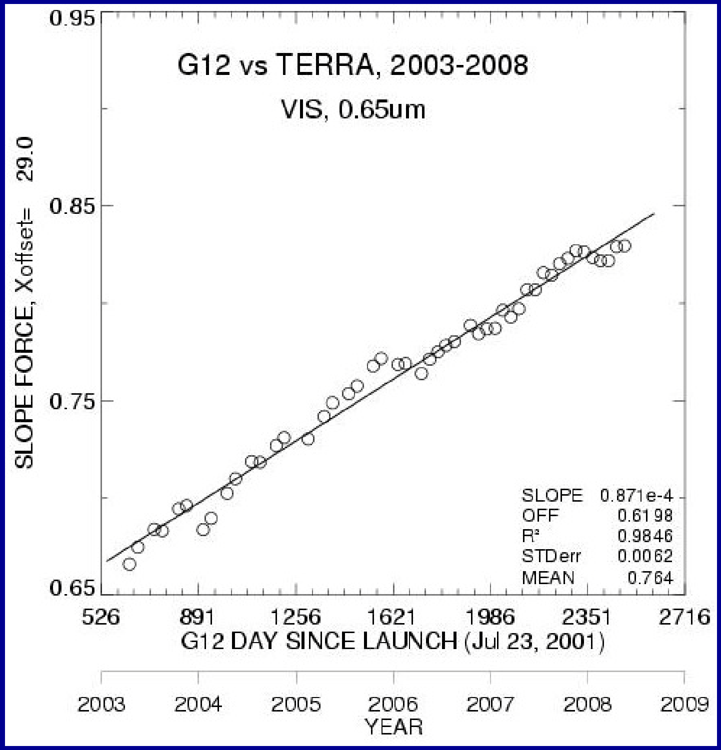
Satellite Intercalibrations Ongoing

Visible & infrared channels of GEO imagers & AVHRRs calibrated against MODIS

G12 VIS fit vs. Terra MODIS
May 2008



Gains for force fit through
G12 space count



Regression fits of slopes used to predict calibration months ahead of time

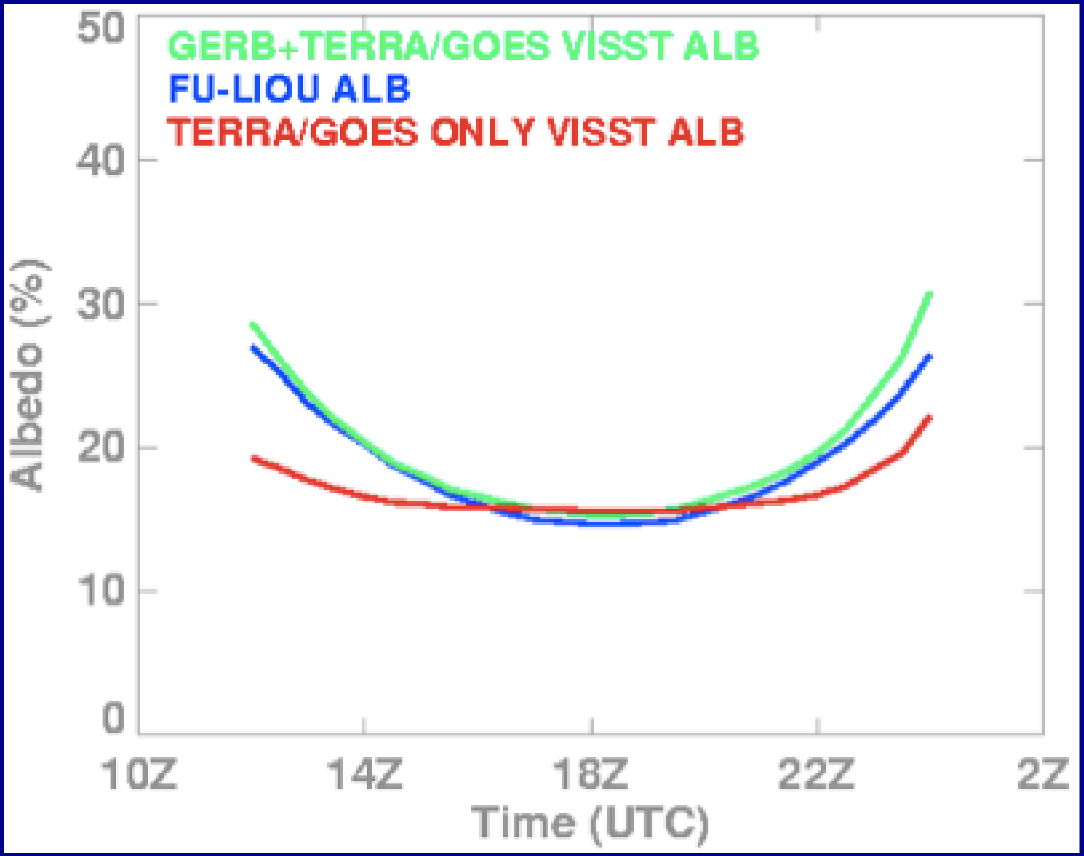
Visible channels on MTSAT & FY-2C, 2D very difficult to calibrate, aliasing

SZA Dependence of Shortwave TOA Albedo

- Conversion from VIS to SW albedo based on correlations with CERES SW data; CERES in Sun-synch orbit
  - no SZA dependence
  - SZA biased albedos

- GERB on Meteosat coincident with SEVIRI VIS
  - SZA dependence

- Normalized GERB results used to adjust albedos from GOES, MTSAT, etc.



Khaiyer poster

Surface Skin Temperature Retrievals

• Satellite imager 10.8-µm temperature, T_{11}, is adjusted for attenuation to estimate the surface leaving radiance, L_{se}. Surface skin temperature is

$$T_s = B^{-1}(\varepsilon_s L_{se})$$

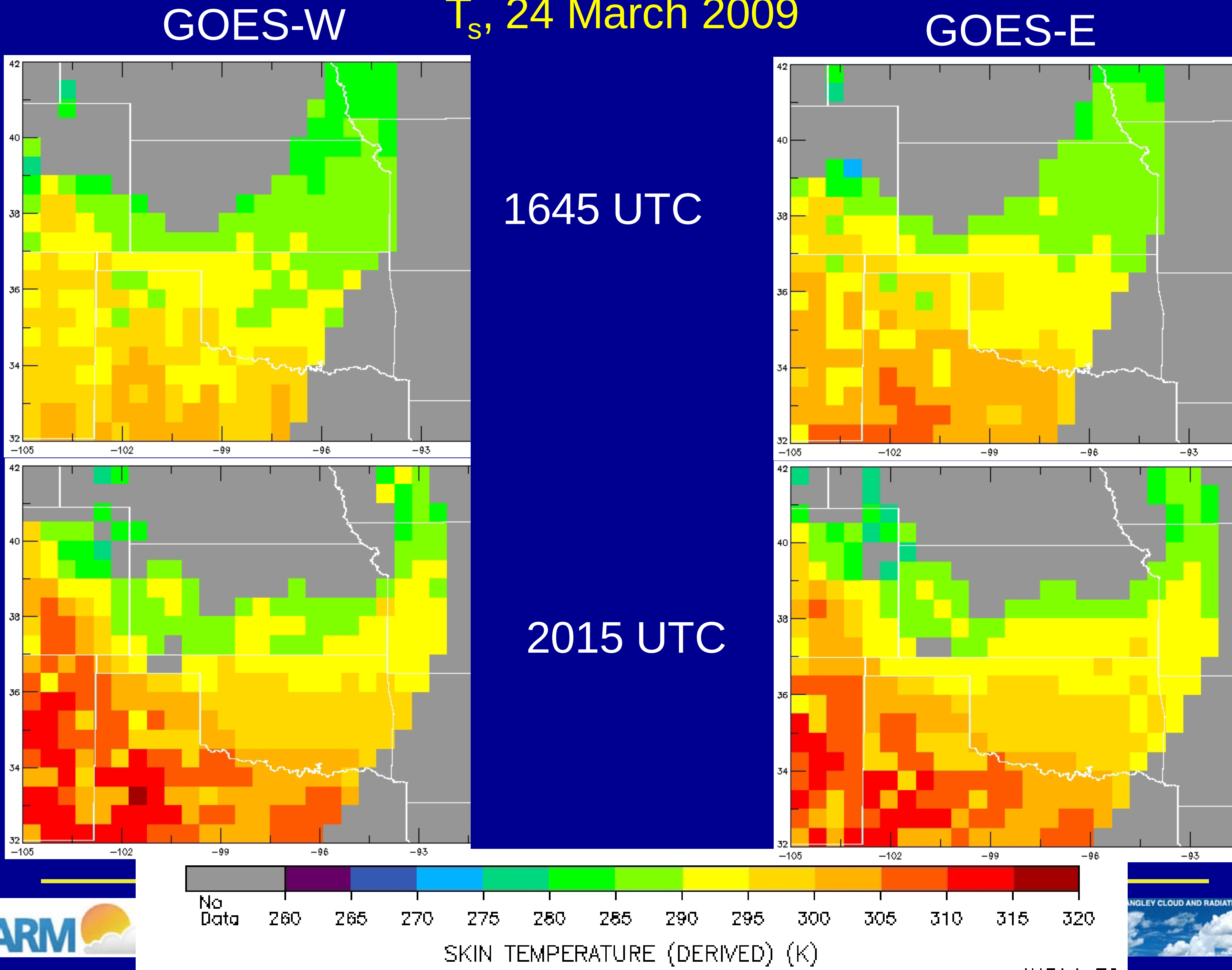
- surface emissivity ε_s from CERES MODIS analyses

• Mean T_s is provided for any region having cloud amounts < 80%

- 0.5° or 1° gridded product
- merged with model T_s for cloudy regions for separate product

• Produced for most domains

T_s, 24 March 2009



ARM

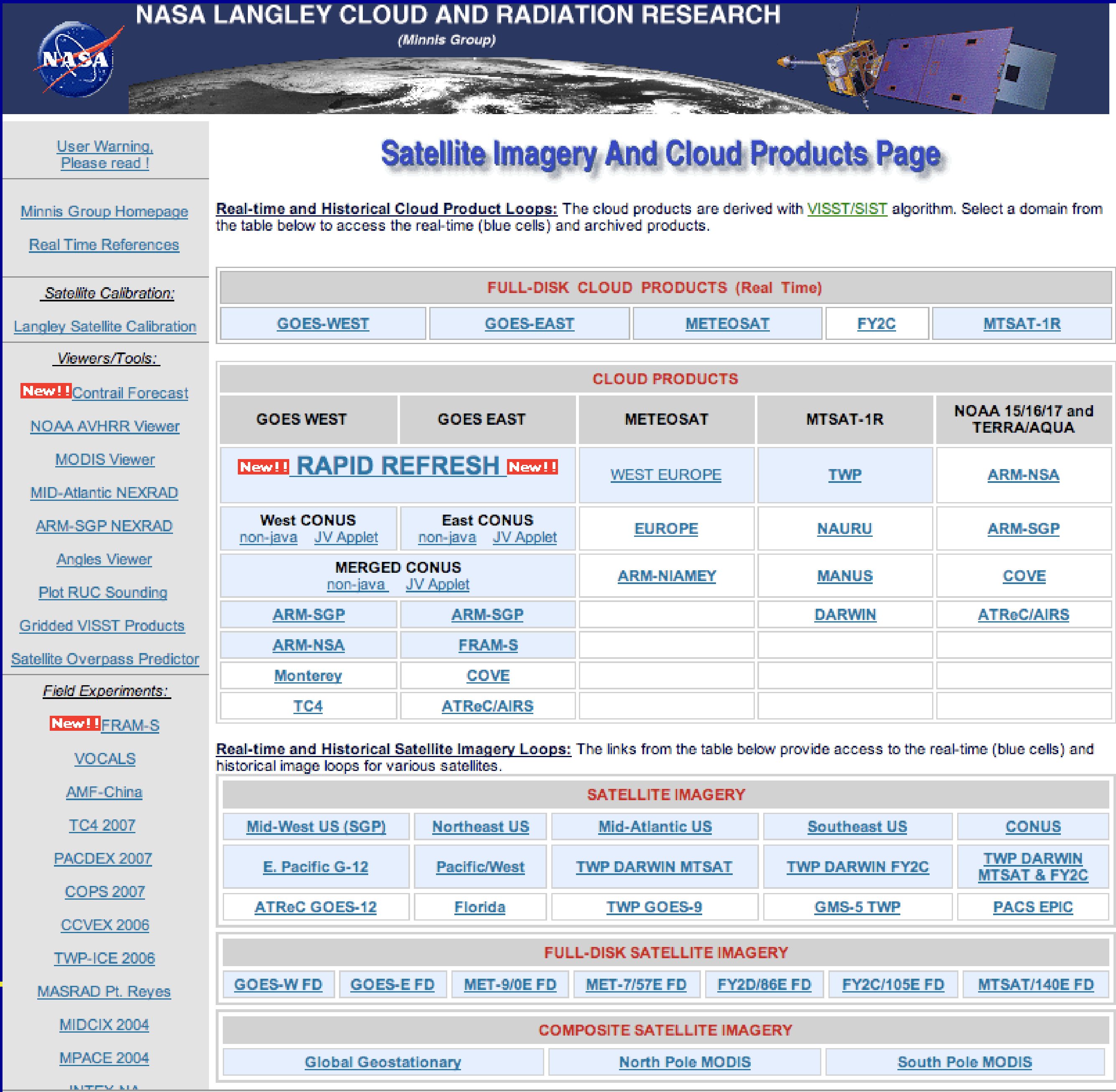
Domains & Data

http://www-angler.larc.nasa.gov

Cloud analyses:

- full disk, lo-res
- large N. Amer domains
- ARM sites:
  - fixed & AMF
- various field programs, FRAM-S
- gridded results

Other tools/viewers



NASA LANGLEY CLOUD AND RADIATION RESEARCH

(Minnis Group)

User Warning, Please read !

Minnis Group Homepage

Real Time References

Satellite Calibration:

Langley Satellite Calibration

Viewers/Tools:

New!! Contrail Forecast

NOAA AVHRR Viewer

MODIS Viewer

MID-Atlantic NEXRAD

ARM-SGP NEXRAD

Angles Viewer

Plot RUC Sounding

Gridded VISST Products

Satellite Overpass Predictor

Field Experiments:

New!! FRAM-S

VOCALS

AMF-China

TC4 2007

PACDEX 2007

COPS 2007

CCVEX 2006

TWP-ICE 2006

MASRAD Pt. Reyes

MIDCIX 2004

MPACE 2004

Satellite Imagery And Cloud Products Page

Real-time and Historical Cloud Product Loops: The cloud products are derived with VISST/SIST algorithm. Select a domain from the table below to access the real-time (blue cells) and archived products.

FULL-DISK CLOUD PRODUCTS (Real Time)				
GOES-WEST	GOES-EAST	METEOSAT	FY2C	MTSAT-1R

CLOUD PRODUCTS				
GOES WEST	GOES EAST	METEOSAT	MTSAT-1R	NOAA 15/16/17 and TERRA/AQUA
New!! RAPID REFRESH New!!		WEST EUROPE	TWP	ARM-NSA
West CONUS non-java JV Applet	East CONUS non-java JV Applet	EUROPE	NAURU	ARM-SGP
MERGED CONUS non-java JV Applet		ARM-NIAMEY	MANUS	COVE
ARM-SGP	ARM-SGP		DARWIN	ATReC/AIRS
ARM-NSA	FRAM-S			
Monterey	COVE			
TC4	ATReC/AIRS			

Real-time and Historical Satellite Imagery Loops: The links from the table below provide access to the real-time (blue cells) and historical image loops for various satellites.

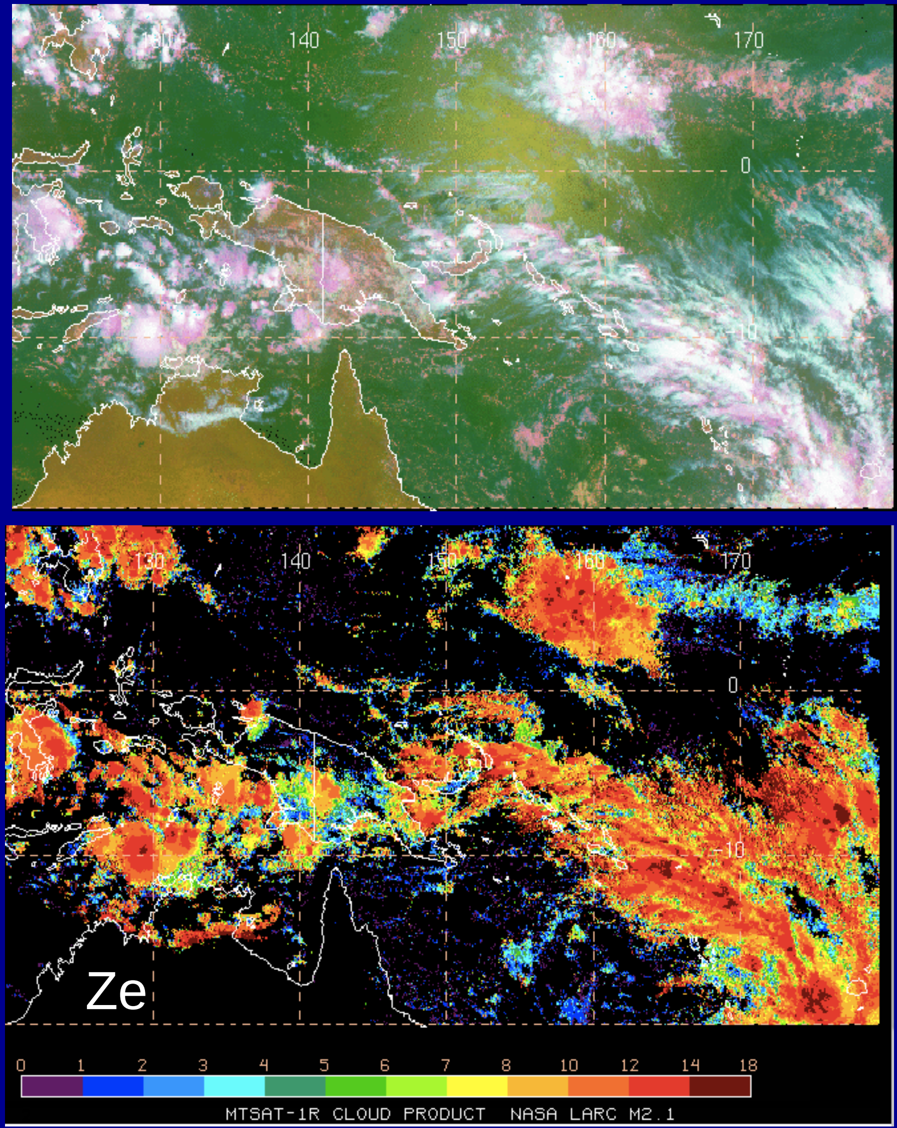
SATELLITE IMAGERY				
Mid-West US (SGP)	Northeast US	Mid-Atlantic US	Southeast US	CONUS
E. Pacific G-12	Pacific/West	TWP DARWIN MTSAT	TWP DARWIN FY2C	TWP DARWIN MTSAT & FY2C
ATReC GOES-12	Florida	TWP GOES-9	GMS-5 TWP	PACS EPIC

FULL-DISK SATELLITE IMAGERY						
GOES-W FD	GOES-E FD	MET-9/0E FD	MET-7/57E FD	FY2D/86E FD	FY2C/105E FD	MTSAT/140E FD

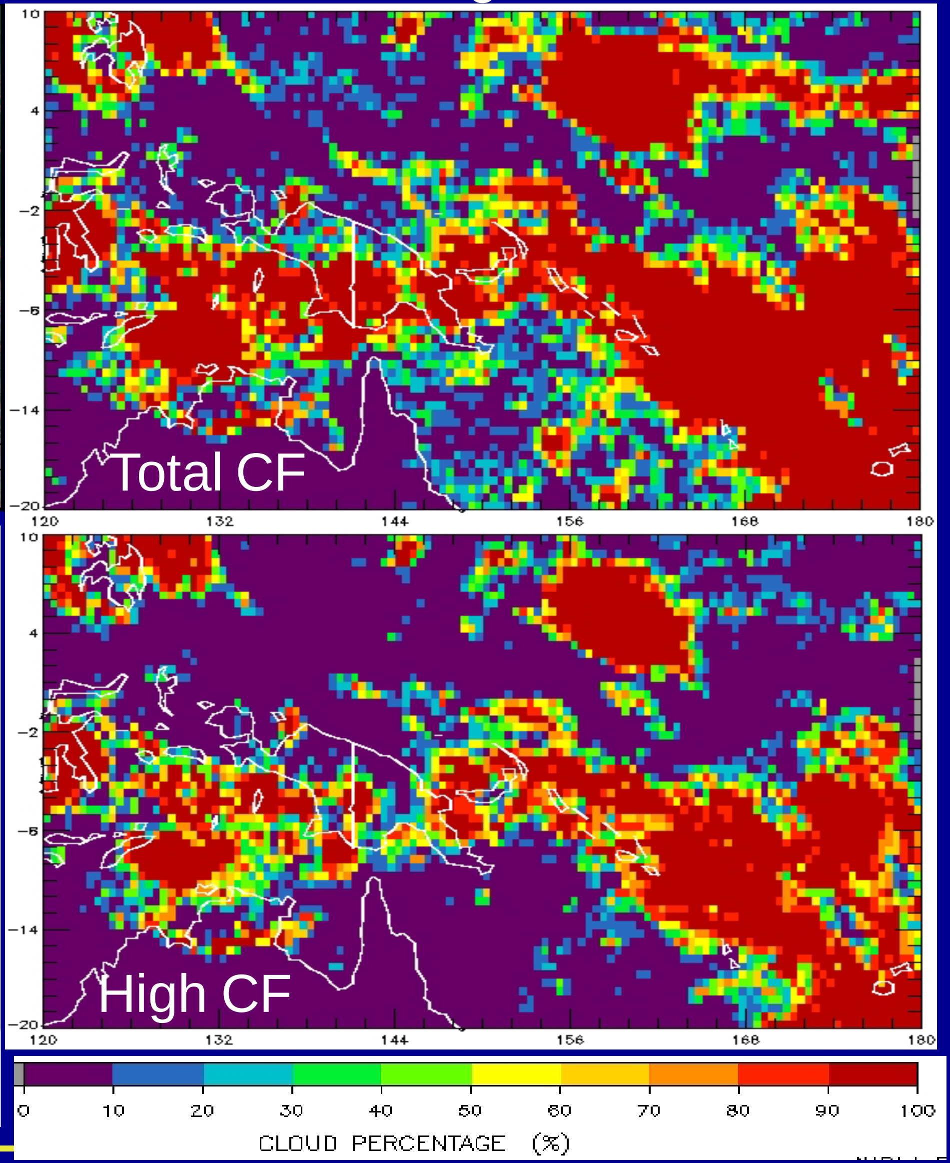
COMPOSITE SATELLITE IMAGERY		
Global Geostationary	North Pole MODIS	South Pole MODIS

Gridded Data Example, TWP, 0030 UTC, 30 Mar 2009

Pixel level



0.5° grid



Domains & Data - 2

Cloud analyses:

- results provided directly over sites

- digital data access

ATReC 2003
THORPEX
CRYSTAL
ARM SGP
CLAMS
INCA Spring 2000
SAFARI 2000
FIRE Arctic (1999)

Cloud Products derived at Ground Sites

- VISST - Computed from pixel retrievals inside a 10 km or 20 km radius centered on the site.

  + Real Time Sites:

  GOES-W SGP | GOES-E SGP | TWP Nauru | TWP Manus | TWP Darwin | SIRTA France | Chilbolton U.K | Cabauw Netherlands | Lindenberg Germany | Potenza Italy | Atqasuk | Barrow | Oliktok | Toolik | COVE | Niamey Nigeria | COPS |

  + Past IOP Sites:

  Pt.Reyes | CRYSTAL-FACE | ATReC Bangor | ATReC Montreal |

- LBTM - Computed from 3x3 1/3 ° regions centered on the site.

  SGP CART | TWP Nauru | TWP Manus | TWP Darwin |

ARM-NSA & SHEBA Products - Radiation and Cloud Products from satellite data during SHEBA/FIRE-ACE

Access Binary Data and Image Files (GIF, JPEG) on The Disk

- VISST pixel-level cloud products:

  GOES-12 TC4 | AQUA TC4 | TERRA TC4 | GOES-12 SGP | GOES-W SGP | GOES-8 SGP | GOES-9 TWP | GOES-W CONUS | GOES-12 CONUS | GOES-8 PACS | GOES-8 CRYSTAL | ATReC/AIRS | GOES-10 Pt. Reyes | MTSAT-1R TWP | MTSAT-1R Darwin | MTSAT-1R Nauru | MTSAT-1R Manus |

- VISST cloud product GIF images:

  GOES-12 TC4 | AQUA TC4 | TERRA TC4 | GOES-12 SGP | GOES-W SGP | GOES-8 SGP | GOES-9 TWP | GOES-9 DARWIN | GOES-9 NAURU | GOES-9 MANUS | GOES-W CONUS | GOES-12 CONUS | MERGED CONUS | GOES-8 PACS | GOES-8 CRYSTAL | ATReC/AIRS | GOES-10 MIDCIX | GOES-10 Pt. Reyes | MTSAT-1R TWP | MTSAT-1R Darwin | MTSAT-1R Nauru | MTSAT-1R Manus |

- LBTM gridded cloud products:

  ARM-TWP | TWP-Manus | TWP-Nauru | TWP-Darwin |

- Satellite imagery GIF files:

  Midwest | Northeast | Mid-alantic | Southeast | CONUS | Pacific/West | Florida | TWP GSM-5 | TWP GOES-9 | MASRAD | Full disk GOES-W | E. Pacific G-12 | TWP-ICE MTSAT | TWP-ICE FY2C | TWP-ICE MTSAT/FY2C | ATReC GOES-12 | AVHRR CONUS | MODIS CONUS | MODIS VA | AVHRR NSA |

Website address: http://www-angler.larc.nasa.gov/ Last Updated: Jan 16, 2007

Conclusions and Future Work

- Attacking 4D cloud problem from passive satellite imagery
  - Should provide a large scale data resource for modelers & for greater understanding of cloud processes
  - Estimate uncertainties & developing new parameterizations using ARM, CALIPSO, & Cloudsat, CERES, data

- Moving a large part of processing to NASA Columbia supercomputer
  - Near-real time domains will be available faster
  - Frees up computers for more reprocessing, development, & testing
    - *reprocessing will include upgrades to algorithms*
    - *estimates of uncertainties to come*
  - MODIS data will be processed over NSA

- Continue adjustments of priorities with ARM Science Team
  - We want your input & feedback!