CERES Ed4 Cloud Properties, 3rd Delivery

P. Minnis, D. Doelling (calibration), W. Smith (val), D. Painemal (NPP: val)

NASA Langley Research Center, Hampton, VA, USA

S. Sun-Mack (QB), Q. Trepte (mask), F-L. Chang (CO2, ML), T. Chee (web, DM), R. Arduini (RTM), K. Bedka (OT tops), S. Bedka (SIST), R. Brown (QC), Y. Chen (clr props, test runs), S. Gibson (graphics), E. Heckert (web, IG), G. Hong (night tau), M. Khaiyer (val), R. Palikonda (offline testing), B. Scarino (cal), R. Smith (web, NPP), D. Spangenberg (polar), Y. Yi (thickness), C. Yost (phase)

SSAI, Hampton, VA, USA

P. W. Heck (retrieval algo)

CIMSS, U. Wisconsin, Madison, Wi, USA

P. Yang, Y. Xie (ice cloud models)

Texas A&M Univ., College Station, TX, USA

Update of CERES Cloud-related Papers, etc.

Edition-2 related

Painemal, D. and P. Minnis, 2012: On the dependence of albedo on cloud microphysics over marine stratocumulus cloud regimes. *J. Geophys. Res.*, **117**, D06203, doi:10.1029/2011JD017120.

Painemal, D., P. Minnis, J. K. Ayers, and L. O'Neill, 2012: GOES-10 microphysical retrievals in marine warm clouds: Multi-instrument validation and daytime cycle over the Southeast Pacific. Submitted to *J. Geophys. Res.*

Giannecchini, K., X. Dong, B. Xi, P. Minnis, and S. Kato, 2011: Validation of CERES-MODIS Arctic cloud properties using CloudSat/CALIPSO and ARM NSA observations. *AGU Fall Mtg 2011*, 5-9 December, San Francisco, CA, A31C-0084.

Stanfield, R., X. Dong, B. Xi, A. Kennedy, A. Del Genio, P. Minnis, D. Doelling, and N. Loeb, 2011: Comparison of global cloud fraction and TOA radiation budgets between the NASA GISS AR5 GCM simulations and CERES-MODIS observations. *AGU Fall Mtg 2011*, 5-9 December, San Francisco, CA, GC43A-0883.

Yan, H., J. Huang, P. Minnis, and T. Wang, 2012: Comparison of CERES surface radiation fluxes and cloud microphysical properties with surface observations. 1st *Joint AMS-Asia Satellite Meteorol. Conf.*, New Orleans, LA, 22 -26 January, 10B.4.

Edition-4 related

Doelling, D. R., C. Lukashin, P. Minnis, B. Scarino, and D. Morstad, 2012: Spectral reflectance corrections for satellite intercalibrations using SCIAMACHY data. *Geosci. Remote Sens. Lett.*, **9**, 119-123, doi: 10.1109/LGRS.2011.2161751.

Xie, Y., P. Yang, G. W. Kattawar, P. Minnis, Y. Hu, and D. Wu, 2011: Determination of ice cloud models using MODIS and MISR data. *Intl. J. Remote Sens.*, **33** (13), 4219-4253, doi:10:080/01431161.2011.642323.

Update of CERES Cloud-related Papers, etc.

Edition-4 related

Kato, S., F. G. Rose, S. Sun-Mack, W. F. Miller, Y. Chen, D. A. Rutan, G. L. Stephens, N. G. Loeb, P. Minnis, B. A. Wielicki, D. M. Winker, T. P. Charlock, P. W. Stackhouse, K.-M. Xu, and W. Collins, 2011: Computation of top-of-atmosphere and surface irradiances with CALIPSO, CloudSat, and MODIS-derived cloud and aerosol properties. *J. Geophys. Res.*, **116**, D19209, doi:10.1029/2011JD016050.

Doelling, D. R., B. R. Scarino, D. Morstad, A. Gopalan, R. Bhatt, C. Lukashin, and P. Minnis, 2012: The calibration of visible imagers using operational hyperspectral SCIAMACHY radiances. Submitted, *IEEE Trans. Geosci. Remote Sens.*

Heck, P., P. Minnis, R. Palikonda, S. Bedka, C. Yost, Y. Yi, and J. K. Ayers, 2011: Improved methods for and validation of nighttime cloud property retrievals from SEVIRI, GOES, and MODIS. *3rd EUMETSAT Cloud Property Retrieval Workshop, CREW-3*, 15-18 November, Madison, WI.

Trepte, Q., P. Minnis, S. Sun-Mack, and C. Trepte, 2011: A comparison of cloud detection between CERES Ed4 cloud mask and CALIPSO Version 3 Vertical Feature Mask. *3rd EUMETSAT Cloud Property Retrieval Workshop, CREW-3*, 15-18 November, Madison, WI.

Chang, F.-L., P. Minnis, S. Sun-Mack, and R. Palikonda, 2011: Using CALIPSO/CloudSat data to evaluate the multilayer cloud properties retrieved from MODIS and SEVIRI data. *3rd EUMETSAT Cloud Property Retrieval Workshop, CREW-3*, 15-18 November, Madison, WI.

Trepte, Q., P. Minnis, R. Palikonda, K. Bedka, and S. Sun-Mack, 2011: Comparison of cloud detection using the CERES Ed4 and LaRC AVHRR cloud masks and CALIPSO Version 3 Vertical Feature Mask. *AGU Fall Mtg 2011*, 5-9 December, San Francisco, CA, A13B-0234.

Scarino, B., D. R. Doelling, D. Morstad, P. Minnis, and C. Lukashin, 2012: The calibration of LEO and GEO satellite imager radiances using hyper-spectral data from SCIAMACHY. *AMS 8th Ann. Symp. Future Oper. Environ. Satellite Sys.*, New Orleans, LA, 22 -26 January, P494.

Issues from Previous Meeting

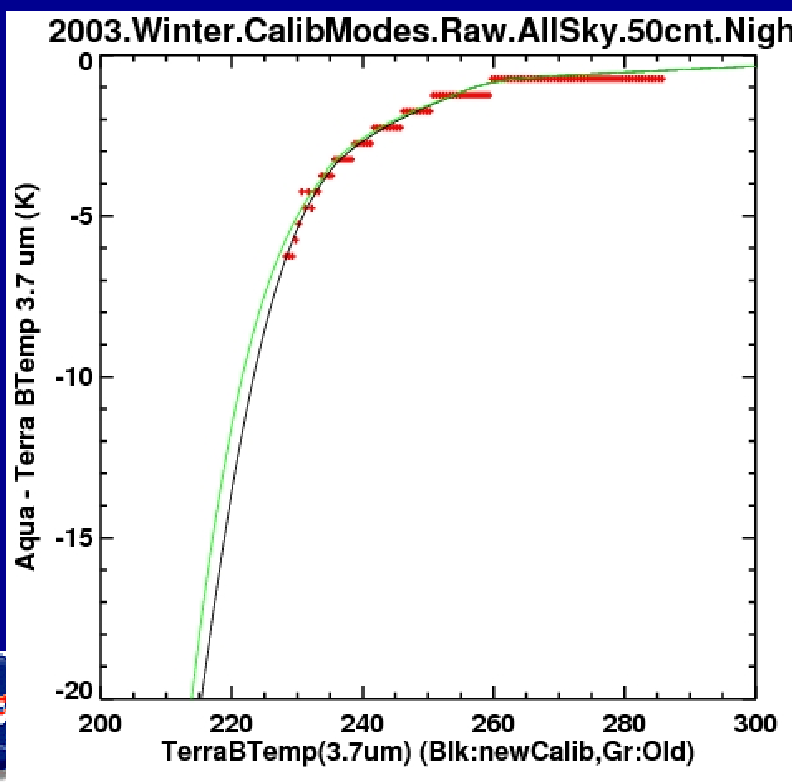
- Ed4 was delivered too soon without thoroughly checking polar clouds
  - *discontinuity line returned*
    - *small in daytime*
    - *significant at night*
  - *cloud fractions at night too high over polar regions*
    - *in some cases > CALIPSO*

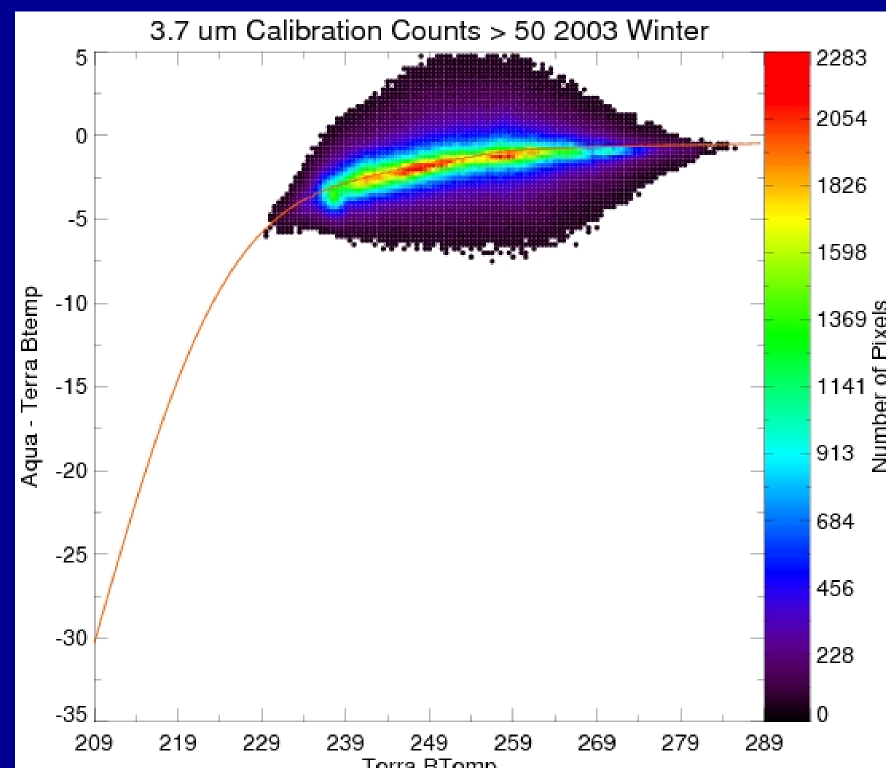
- Ed4 3rd delivery proposed
  - *address discontinuity & source of overestimation*
    - *BTD3.7-11 noise*
    - *T3.7 calibration*
    - *use of nonpolar mask for nonpermanent snow?*
  - *use data from early, mid, and late years*

- Post-meeting discovery
  - *CO2 code used wrong humidity profile*

Terra 3.7-µm Calibration

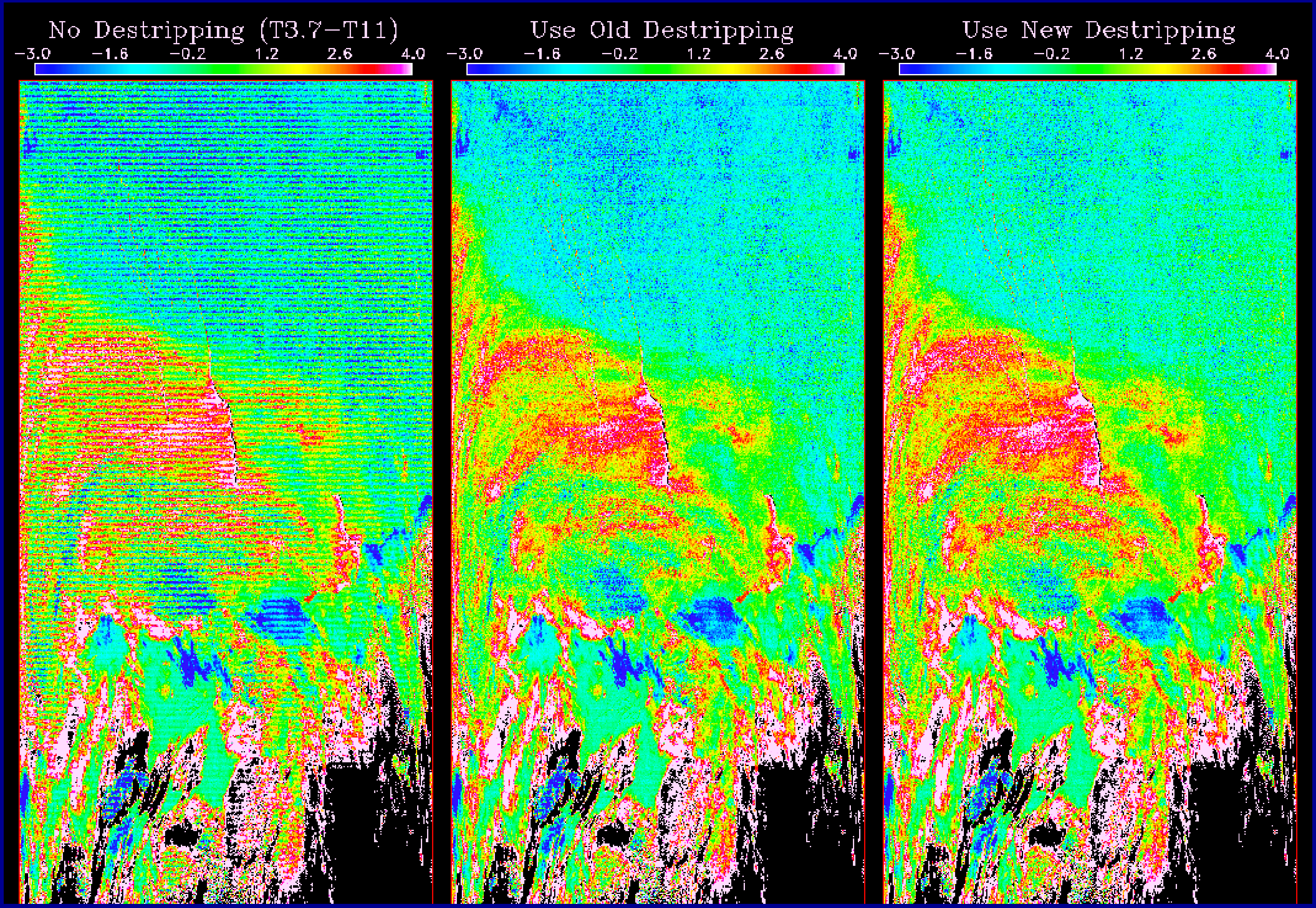
- Developed calibration corrections for all Terra-Aqua seasons
  - matched data with ± 10° VZA, 1 hour
  - computed mean differences for every half degree of Terra
  - retrieved error function fit to mean differences
- Used average correction for each season to pre-Aqua Terra data
- Interpolate between seasons to get monthly corrections
- Add difference to Terra observed value to obtain Aqua equivalent





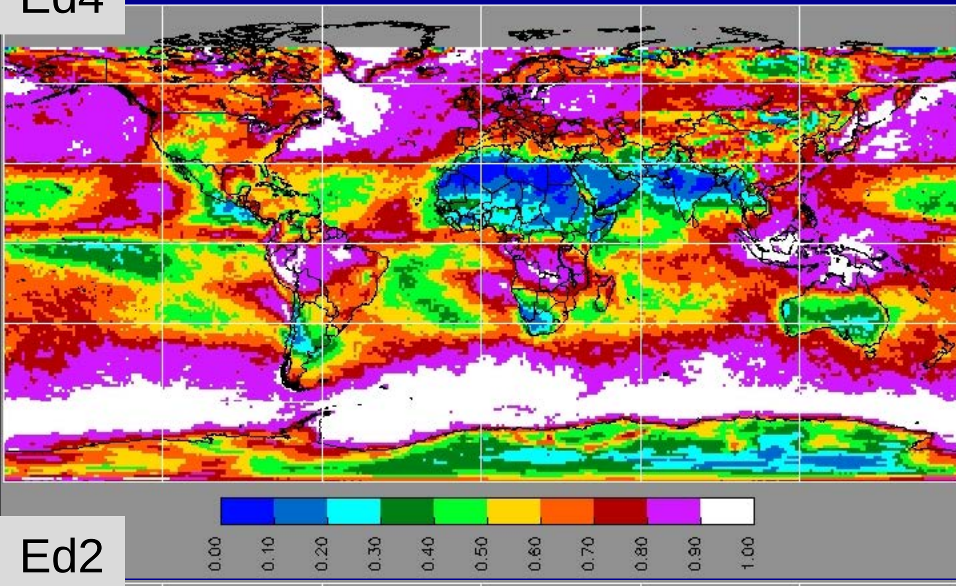
Nighttime 3.7-µm Destriping

- Applied destriping algorithm developed by F. Chang to minimize noisy clouds in the polar regions; improved polar night mask immediately



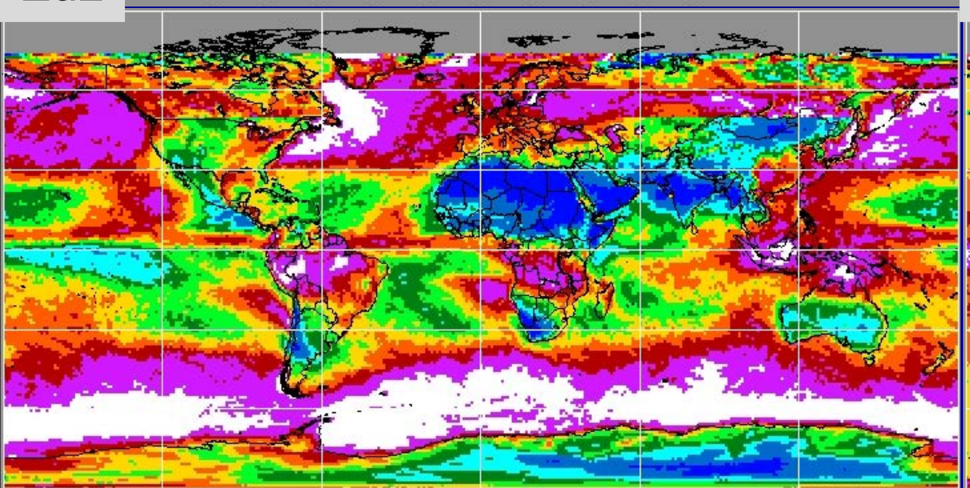
Total Daytime Cloud Fraction: CERES Ed 2 versus Ed 4
Winter 2000/2001

Ed4

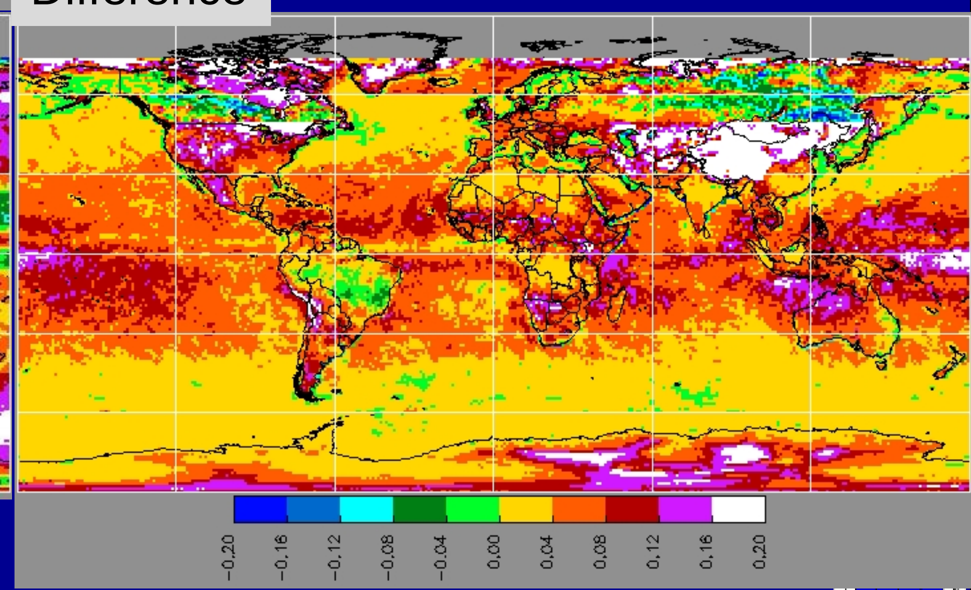


- Increased cloud amounts everywhere except Brazil, Arctic lands
- Trade Cu and dry high altitude greatest increases
- Polar line still evident at 50°N
  - not as prominent

Ed2



Difference



Cloud Mask Changes since last STM

- Daytime tropical ocean: Refined heavy dust and low clouds tests in Sun glint and non-glint ocean, reduced false clouds from Sahara dust storm and meanwhile maintained the daytime ocean cloud fraction.

- Daytime non-polar high latitude land: Reduced false clouds over high-elevated deserts and improved dark and melting snow detections.

- Redefined NH polar regions for summer months (Apr - Oct) to apply non-polar mask beyond 60^{o}N to reduce discontinuity lines.

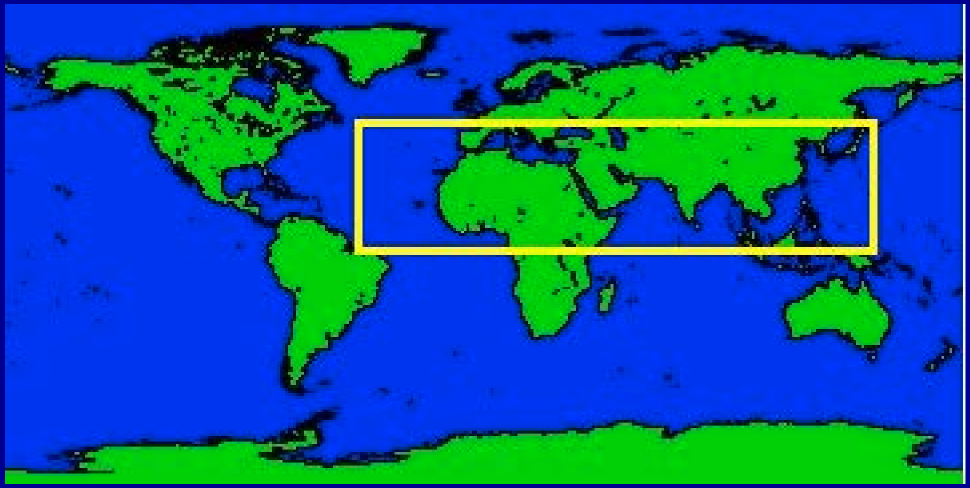
- Daytime polar: Reduced false thin Ci clouds from Ref 1.38 test over the Arctic; Refined the clouds and snow classification for TBD pixels. Reduced the discontinuity lines in NH winter months.

- Twilight polar: Reduced twilight stripping clouds by tightening BTD and reflectance thresholds. Separated Aqua and Terra 2.1 um tests to compensate Terra MODIS 2.1 um stripping at 87<SZA< 88.5.

- Nighttime polar: Reduced discontinuity lines in NH winter months.
  - Reduced false speckle inversion clouds over Arctic land due to noisy BTD3.7-11. Added new inversion clouds tests over Arctic ocean.
  - Improved mid and low clouds tests, added T8.5-T6.7 test over Arctic sea ice.
  - Refined cloud and snow tests for TBD pixel
  - Adjusted clear sky restoration tests.

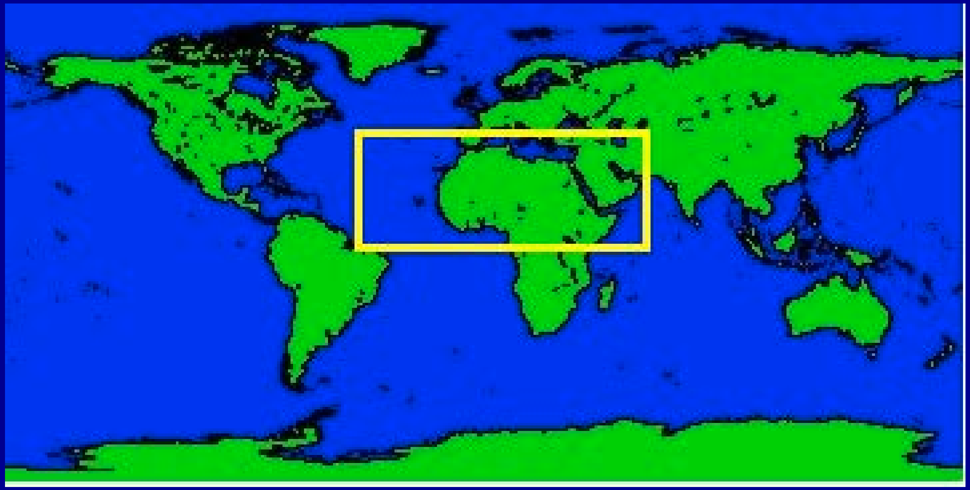
Better distinction between heavy dust and low clouds

Aerosol detection regions
Land and water



Saharan heavy dust box
only over water

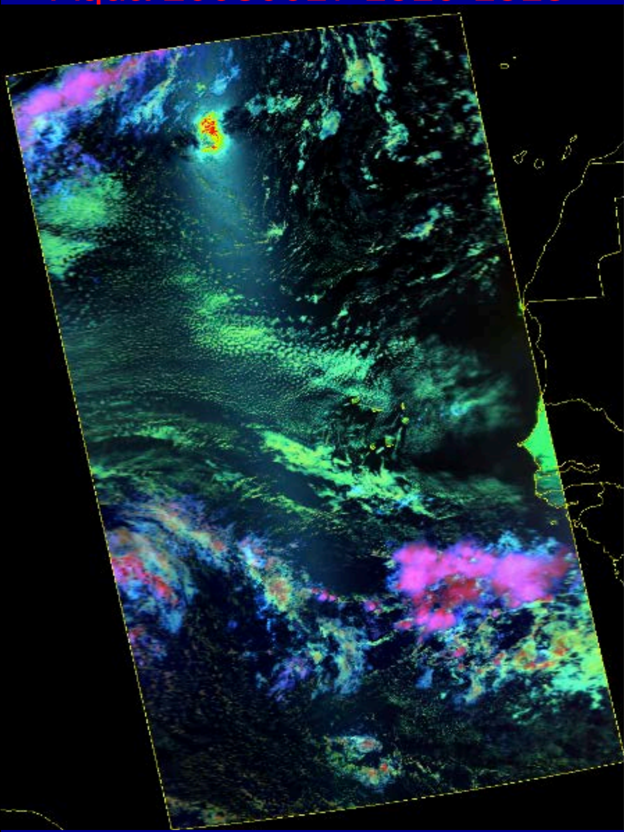
Tests are slightly more liberal to call dust



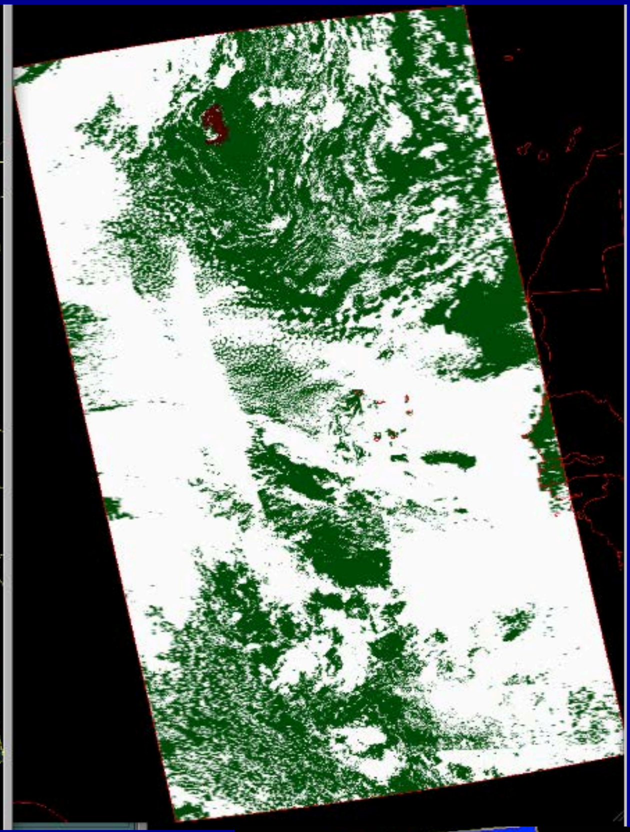
Case 1

Cloud Mask

Aqua 20080617 1510-1515



Mask_Ed4-del2



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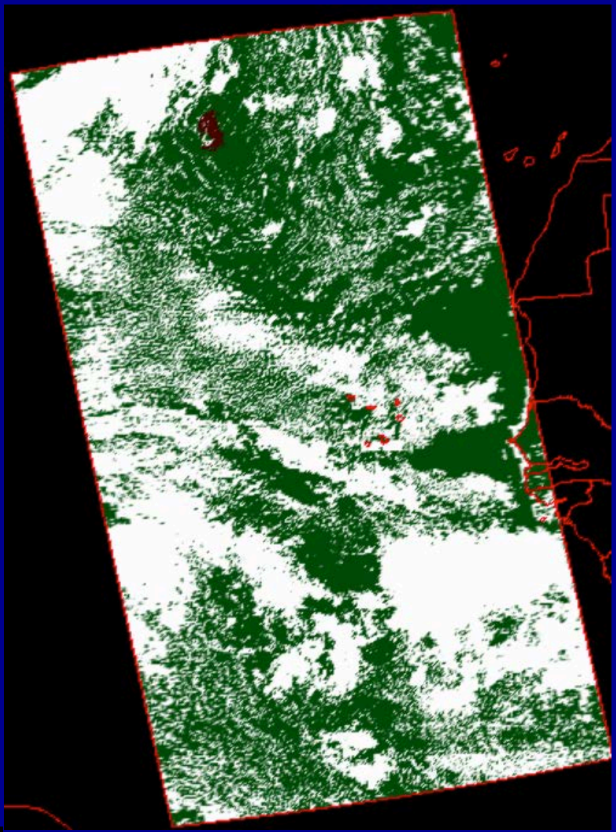
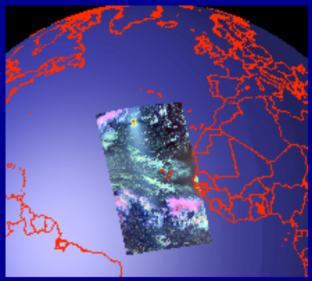
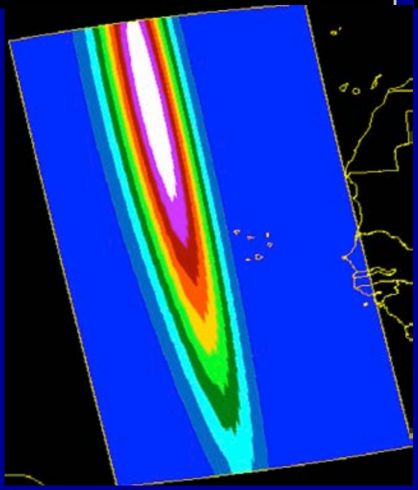




Sun glint probability

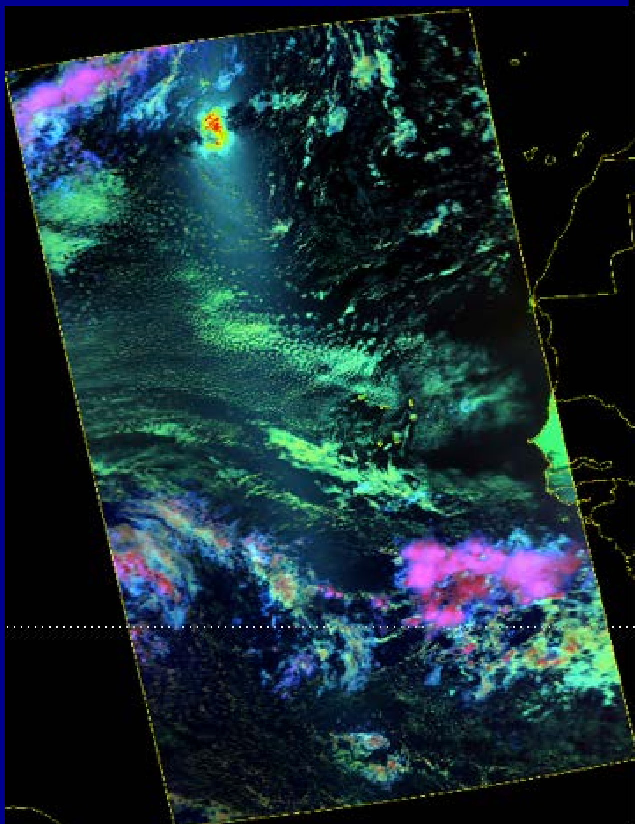


It's an art to keep a good balance between dust and low clouds in Sun glint

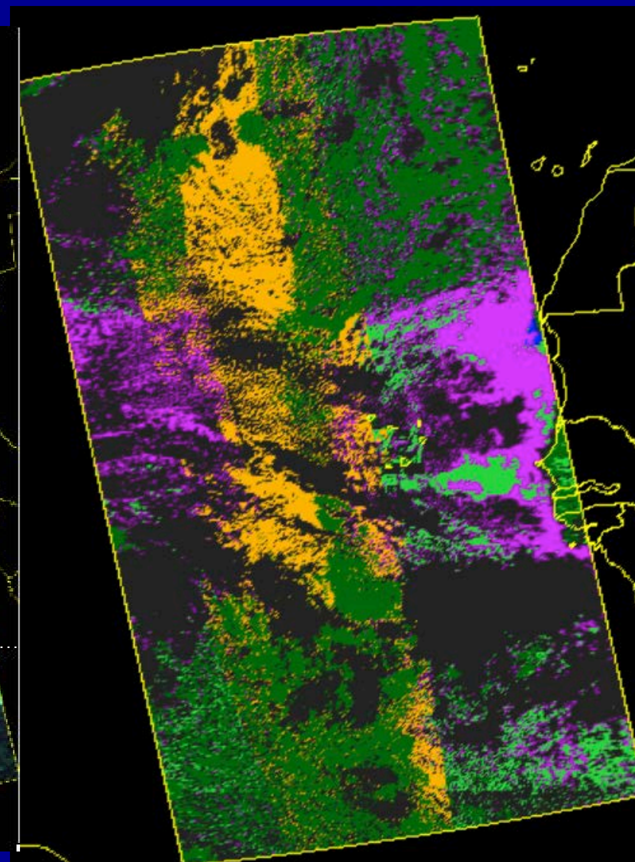
Case 1 cont’

Compare with MODIS-ST

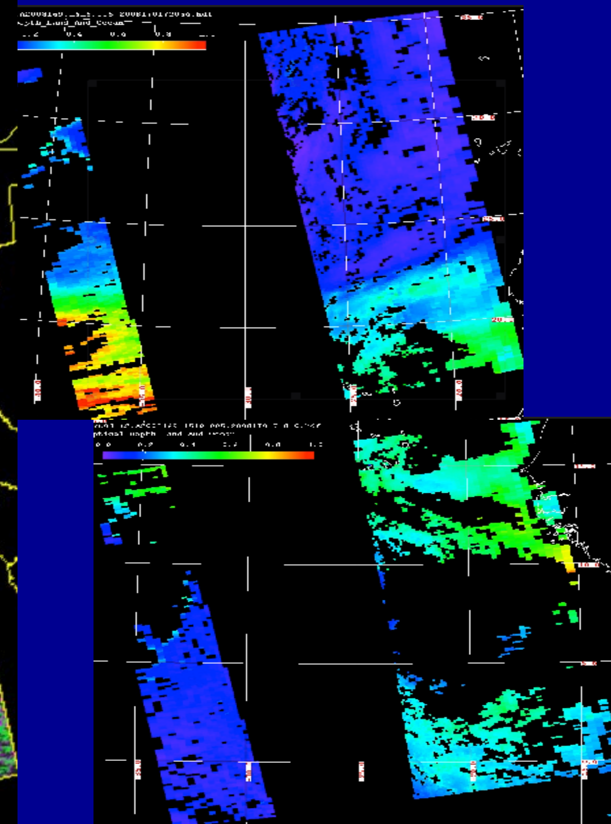
Aqua 20080617 1510-1515



Clear Category_Ed4-del3



MODIS team - Aerosol Optical Depth, MYD04

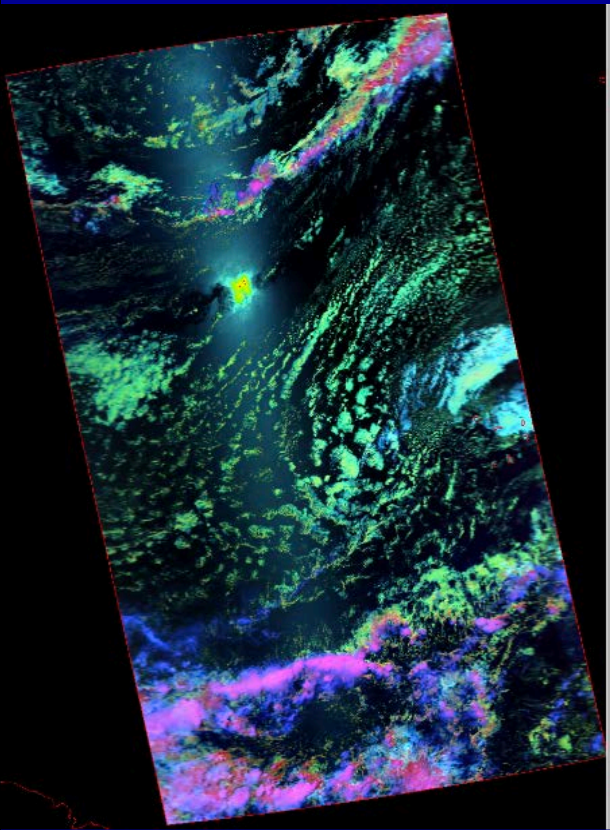


Low clouds and aerosol share similar spectral signals.
It’s difficult to distinguish them, especially in Sun glint.

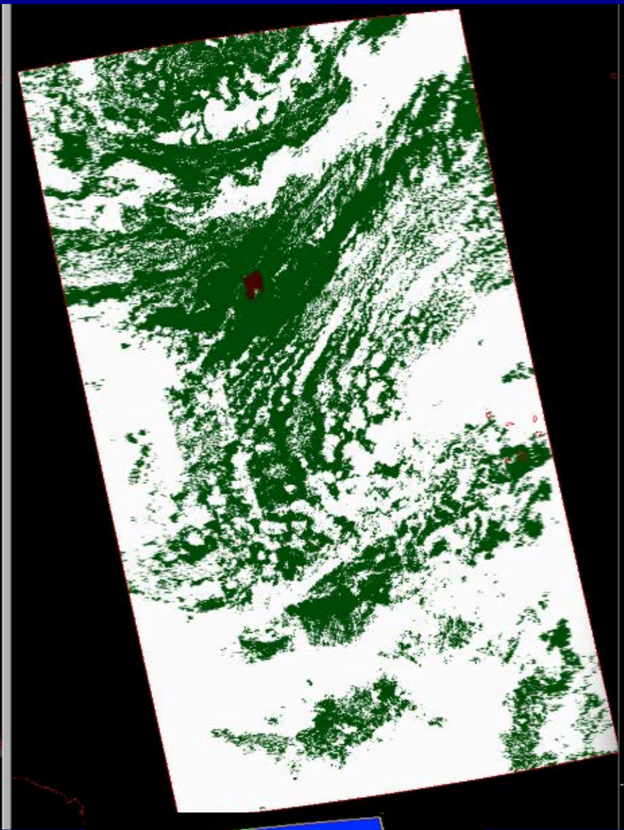
Case 2

Cloud Mask

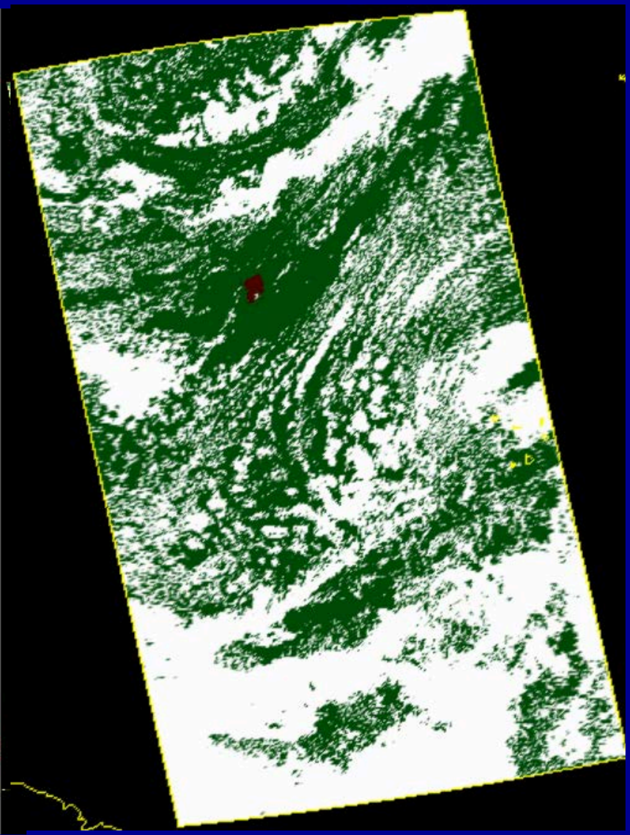
Aqua 20080613 1535-1540

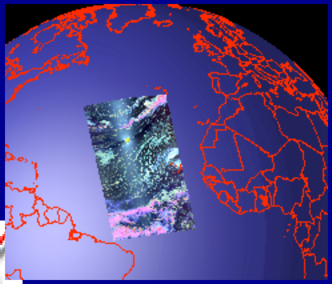


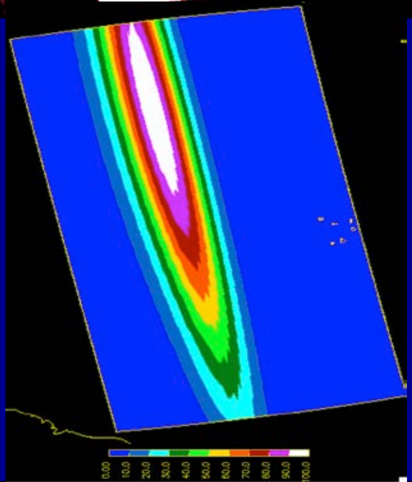
Mask_Ed4-del2



Mask_Ed4-del3







Reduced false clouds along Sun glint boundary

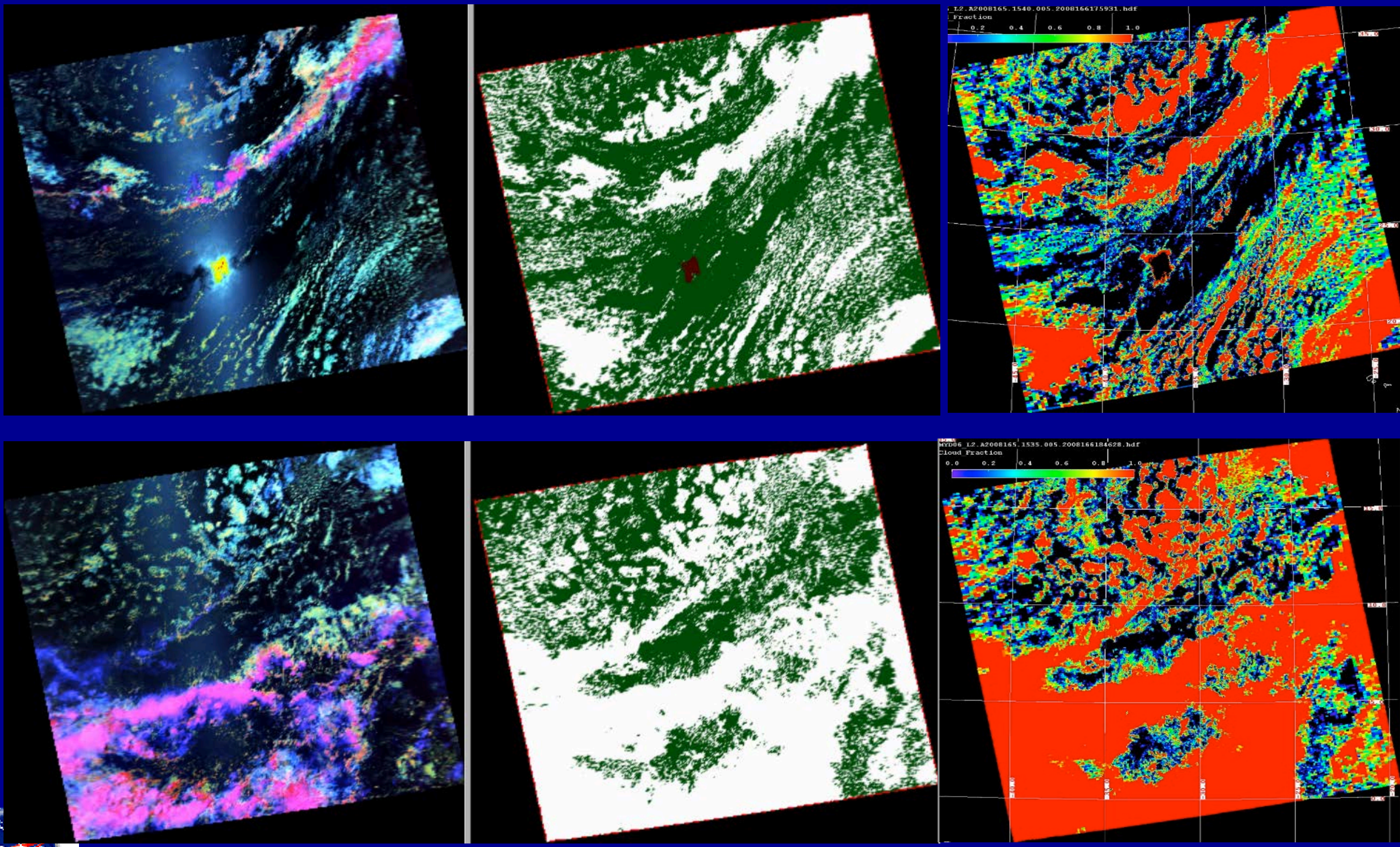
Case 2 cont'

Compare with MODIS-ST

Aqua 20080613 1535-1540

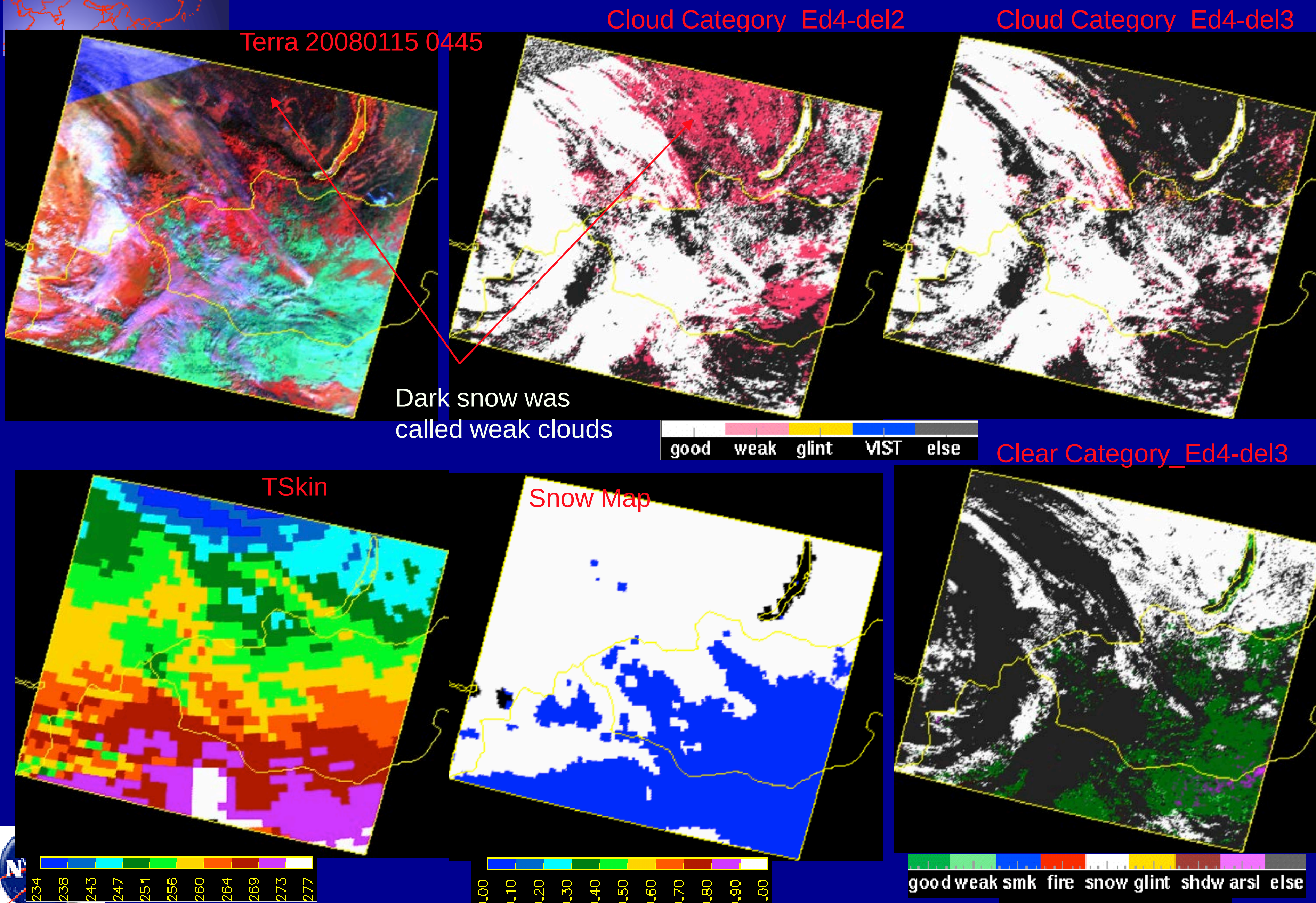
Mask_Ed4-del3

MODIS team - Cloud Fraction MYD06



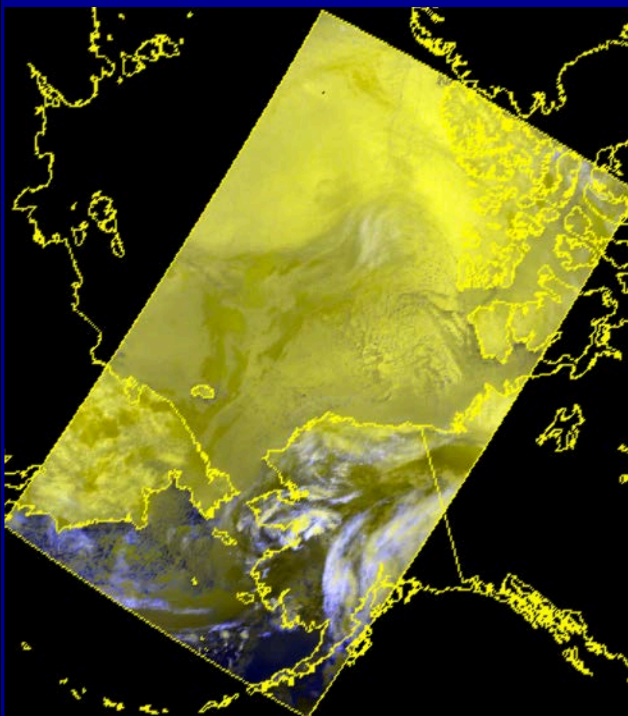
Polar Region Improvements (Daytime, Nighttime, Twilight)

Terra Daytime Transition Zone

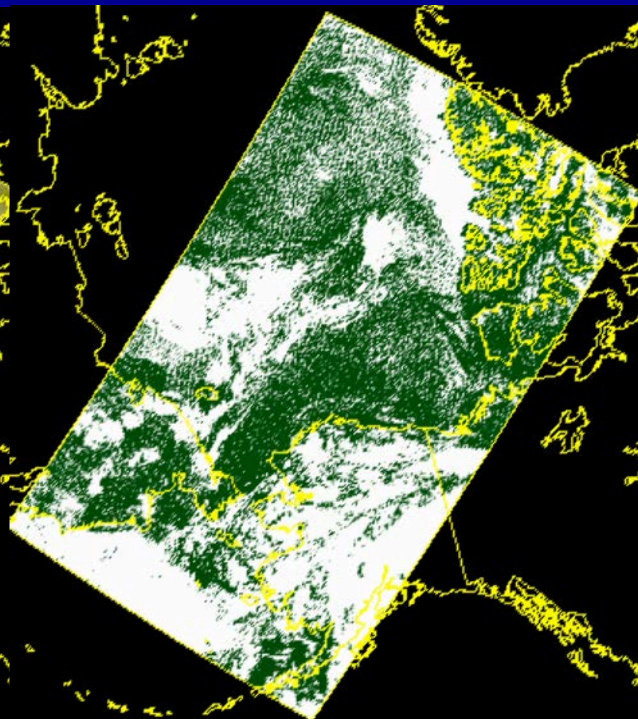


Aqua Arctic Night

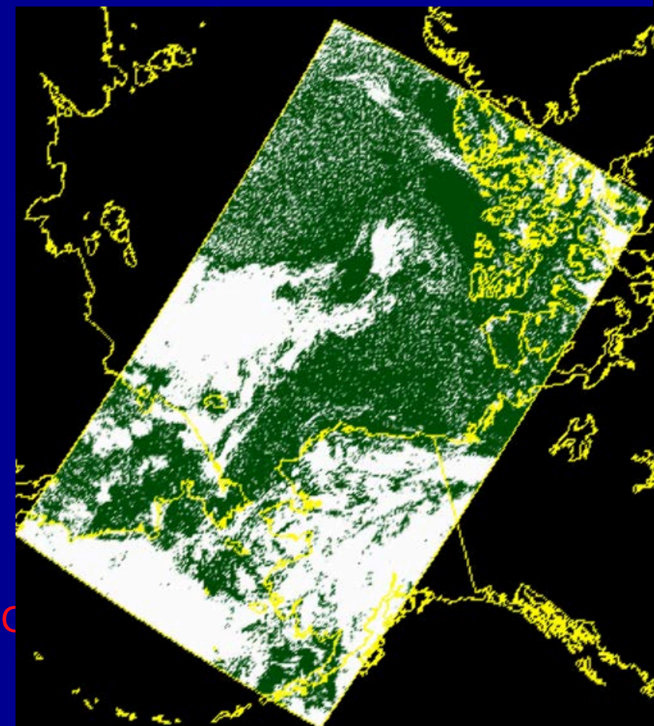
Aqua 20080116 1400-1405



Mask_Ed4-del2



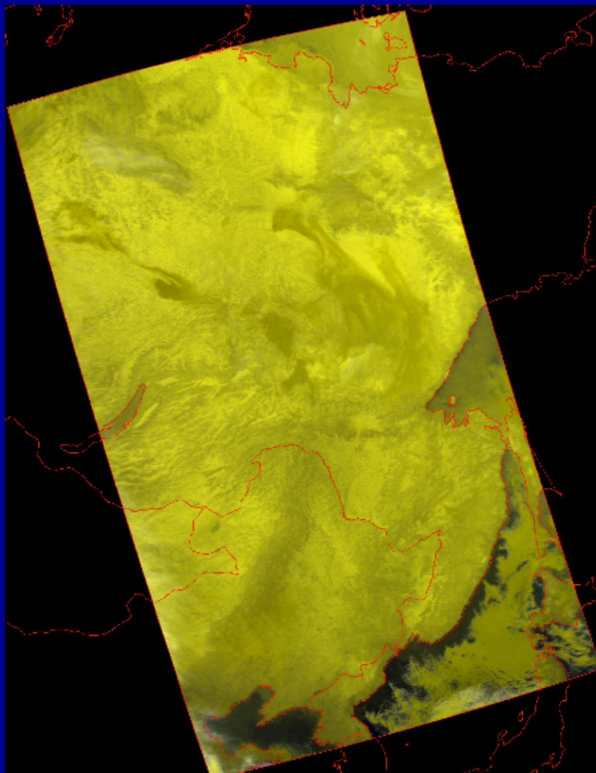
Mask_Ed4-del3



Reduced false spotty clouds, some still remain due to signal noise.

Terra Arctic Night

Terra 20080116 1320-25



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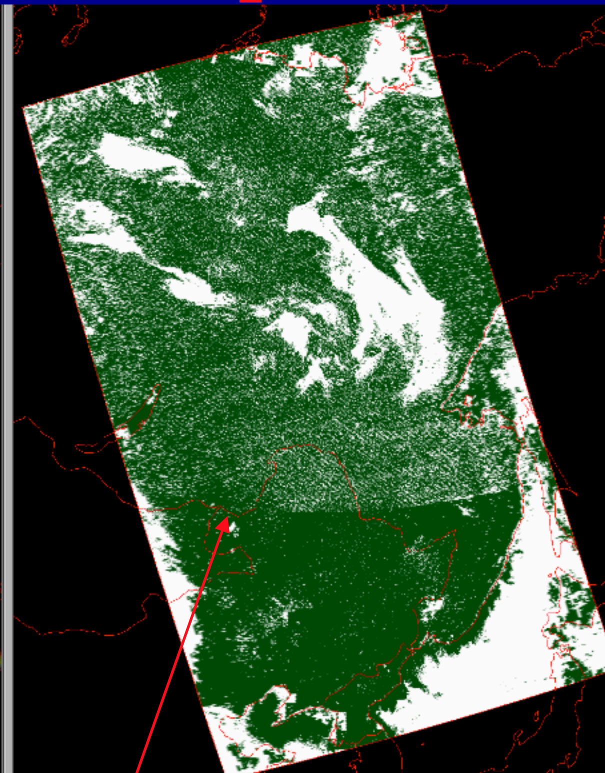

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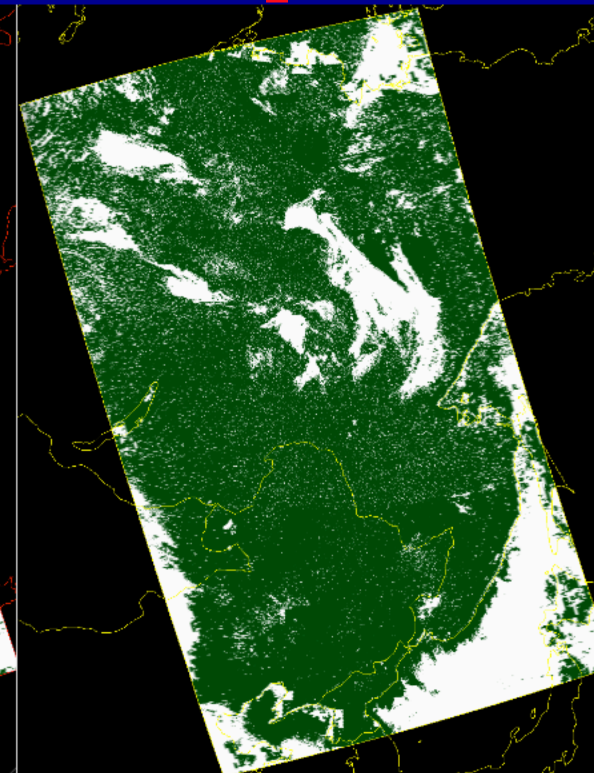
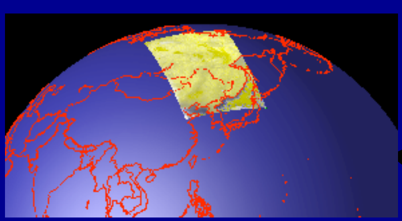
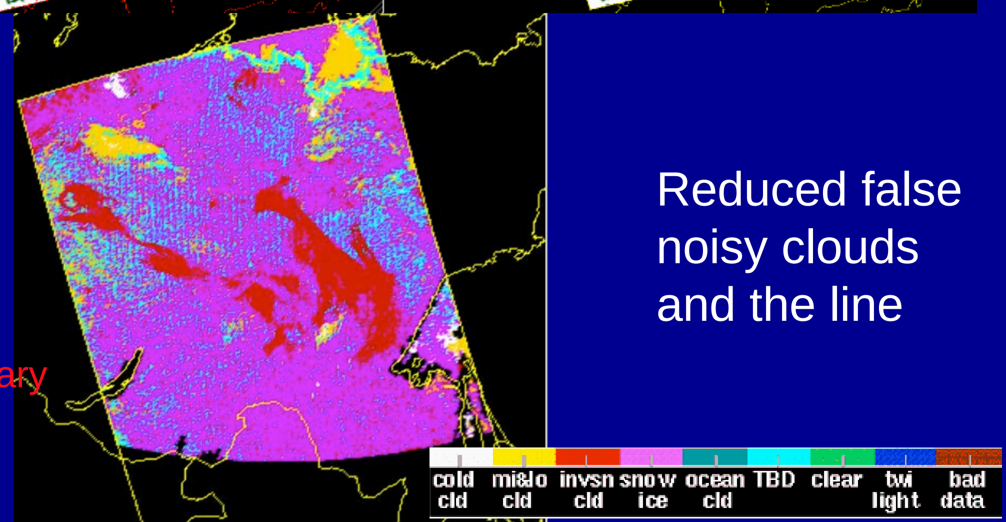


Non-polar to
Polar line

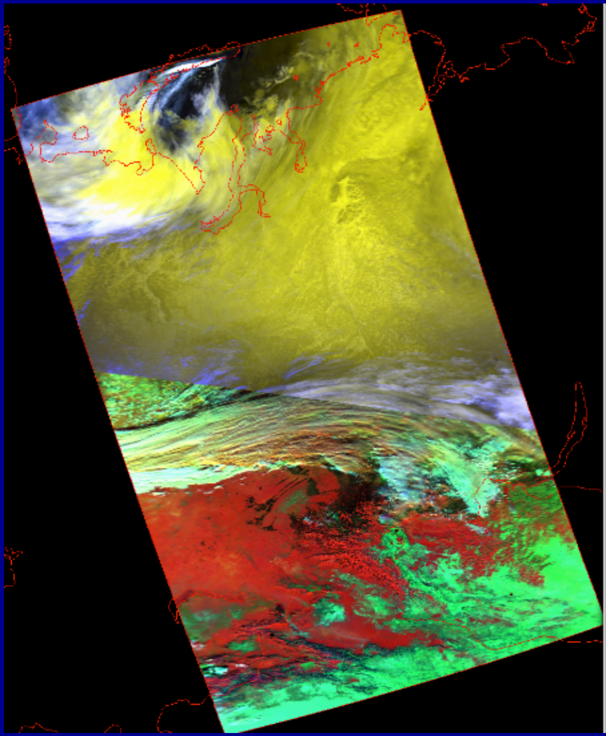


Polar Summary
Ed4-del3



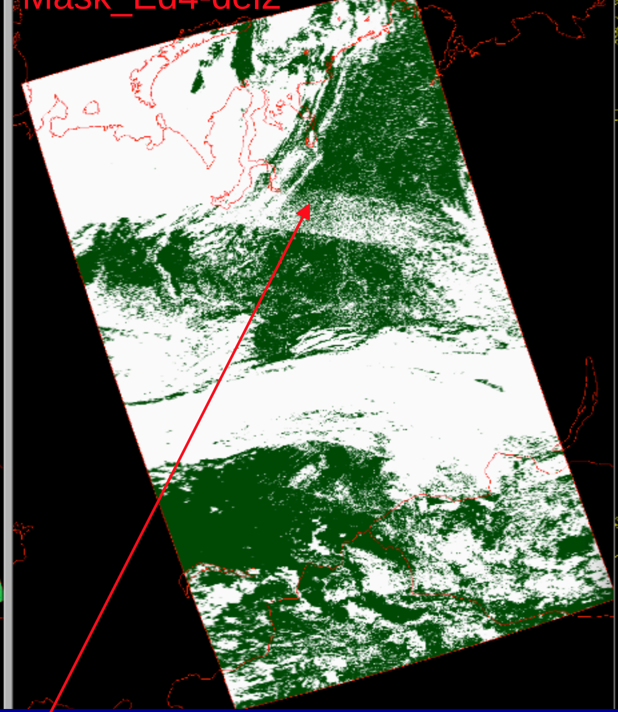
Reduced false noisy clouds and the line

Aqua Arctic Twilight

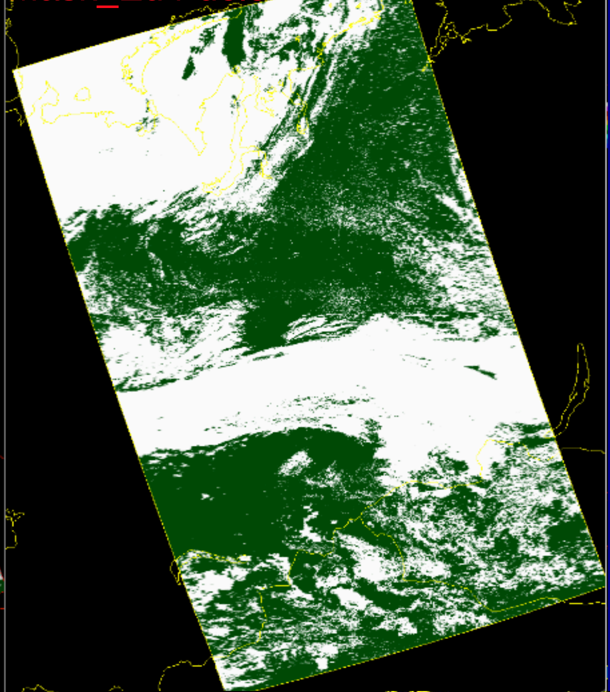


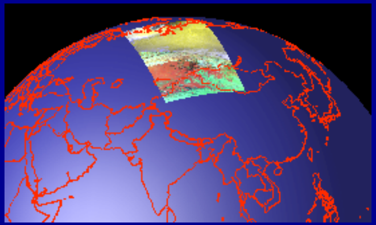
Aqua 20080102 0700-0705

Mask_Ed4-del2



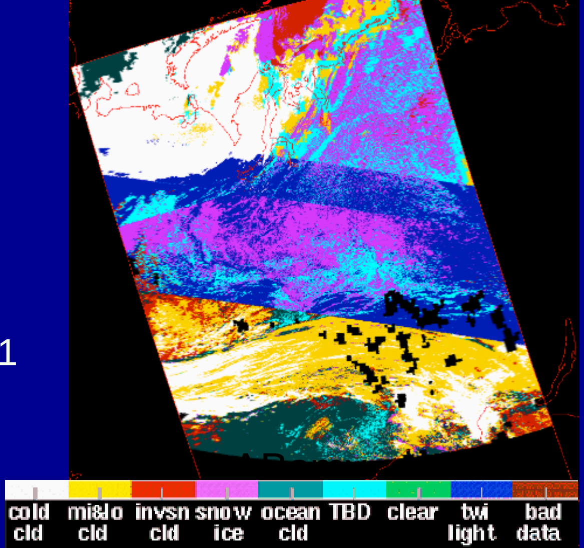
Mask_Ed4-del3



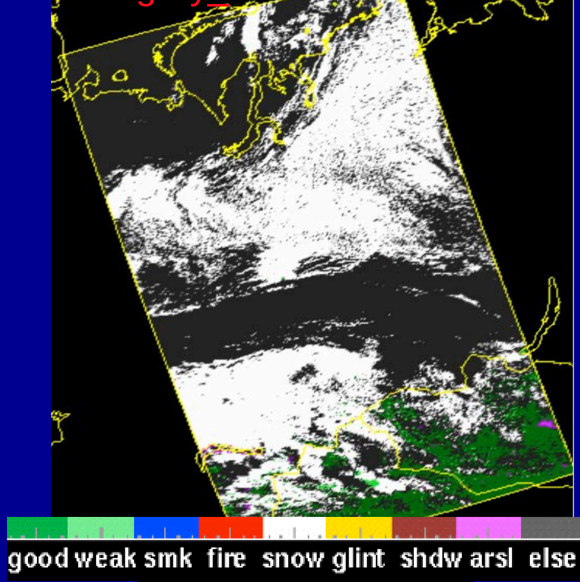


SZA between 88.5 - 91

Polar Summary



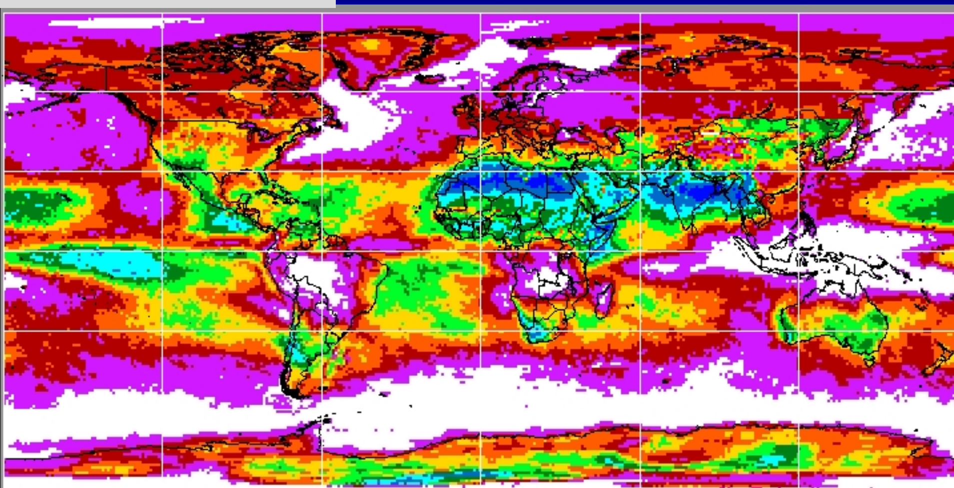
Clear Category_Ed4-del3



Global and Zonal Cloud Fractions

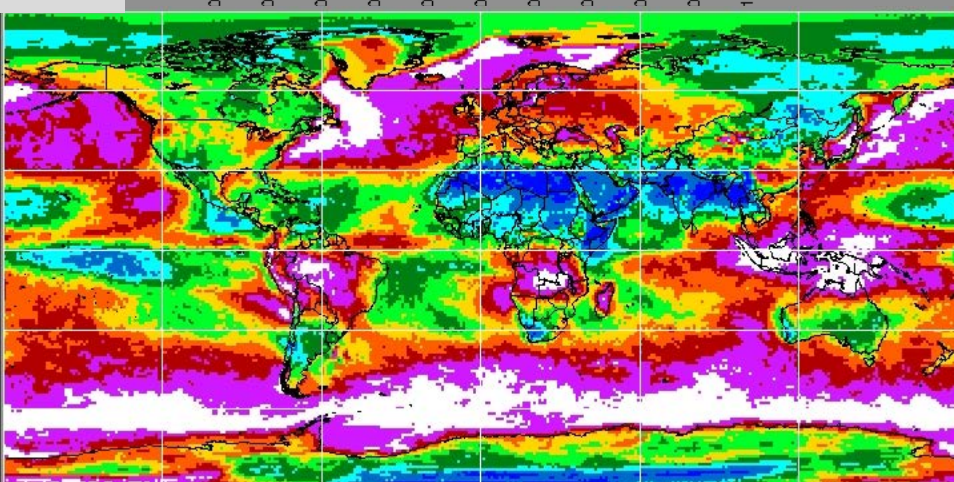
Total Night Cloud Fraction, Winter 2000/2001
CERES Ed 2 versus Ed 4 del2

Ed4 del2

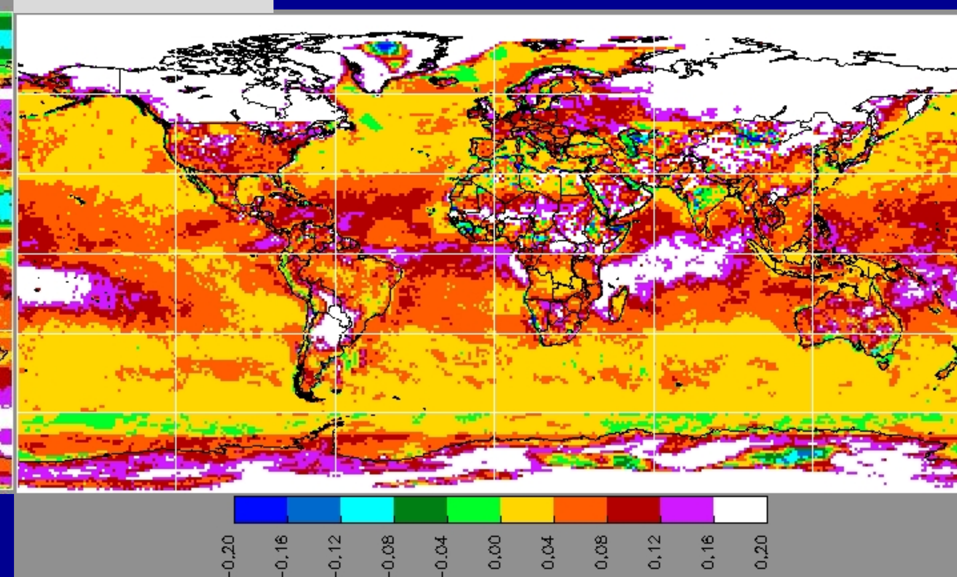


- Increased cloud amounts nearly everywhere
- Trade Cu and polar regions greatest
- Polar line more evident at 50°N

Ed2

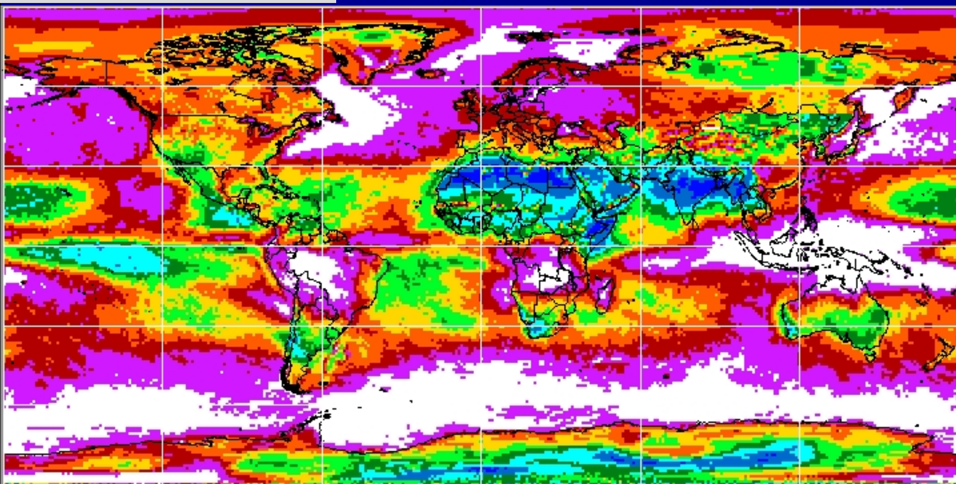


Difference



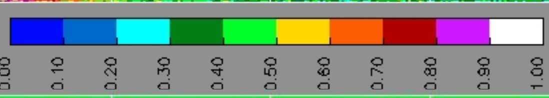
Total Night Cloud Fraction, Winter 2000/2001
CERES Ed 2 versus Ed 4 del3

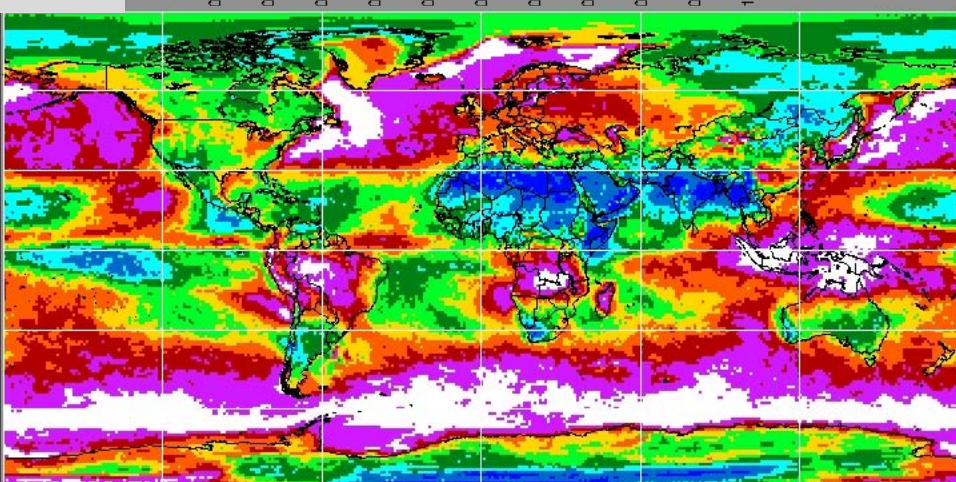
Ed4 del3



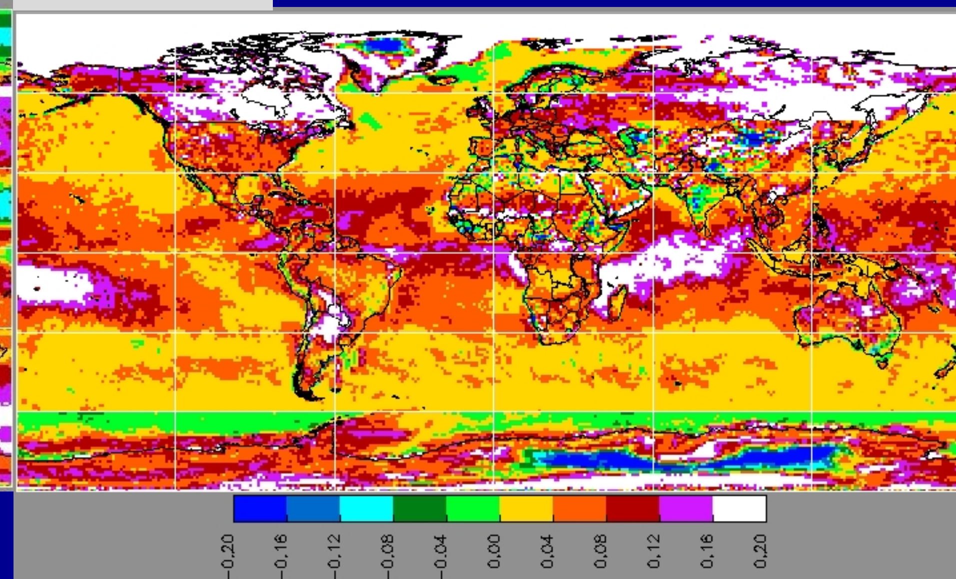
- del3 reduces Arctic clouds
- Trade Cu and polar regions greatest
- Polar line less evident

Ed2





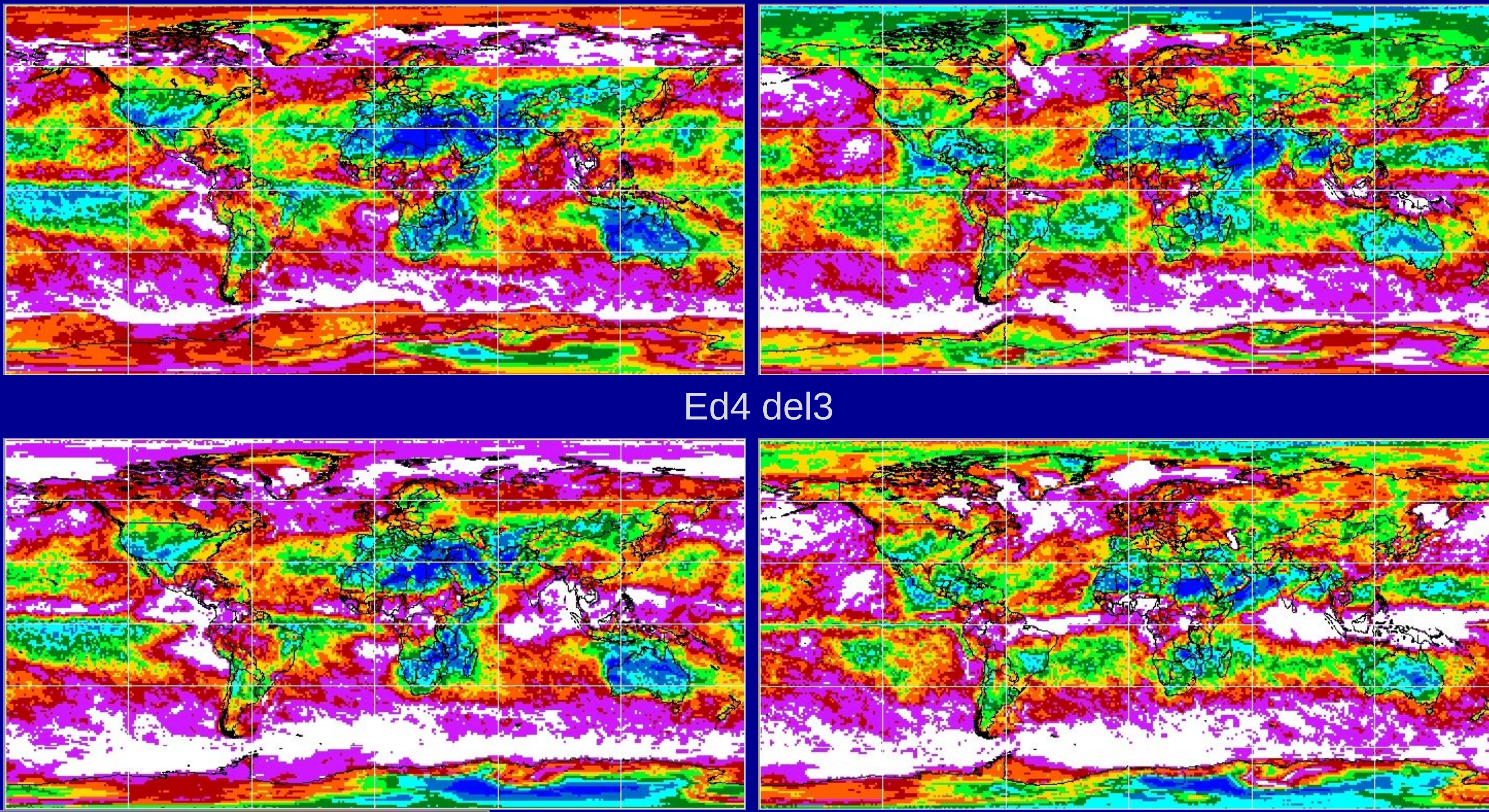
Difference

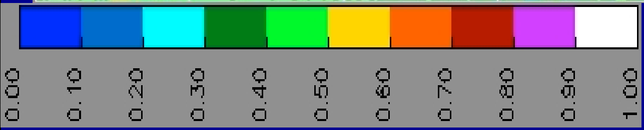


Mean Cloud Fraction, Night, Terra

Sept 2000 Ed2 Apr 2001

Ed4 del3

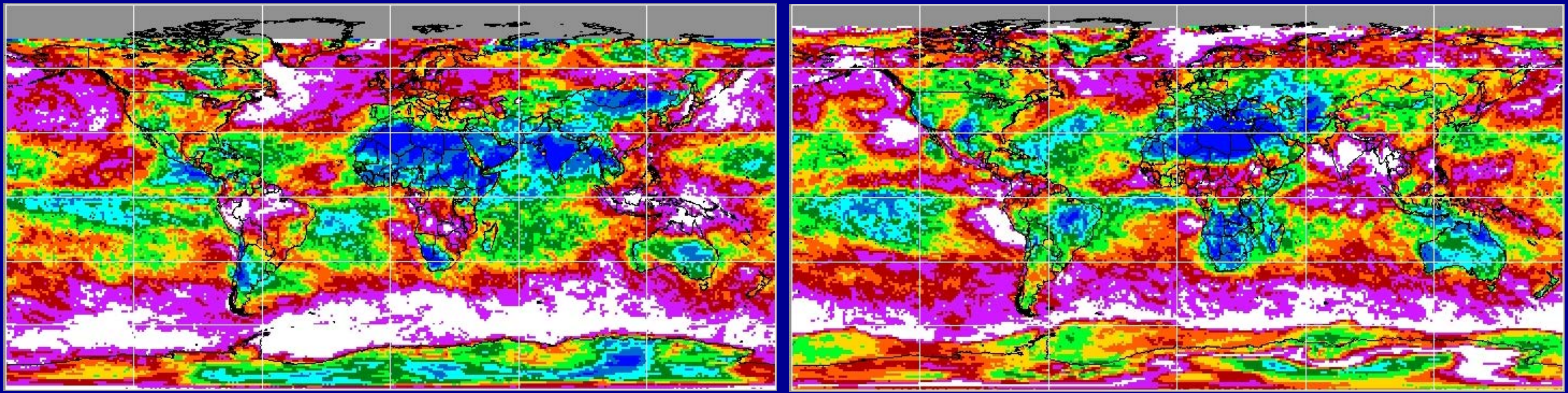




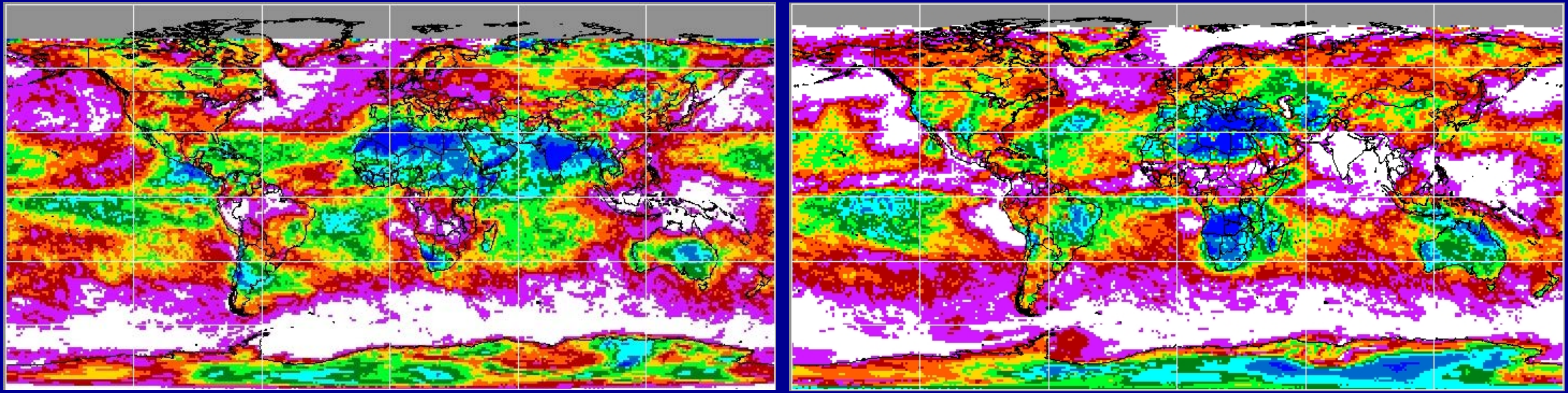
- Polar algorithm line less obvious or missing altogether in new del3
- Nocturnal cover noticeably increased (5.9 & 7.2%)
- No line during daytime in either edition

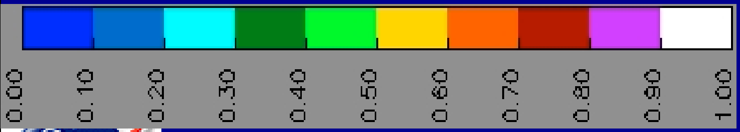
Mean Cloud Fraction, Terra

Day, Feb 2001 Ed2 Night, July 2001



Ed4 del3



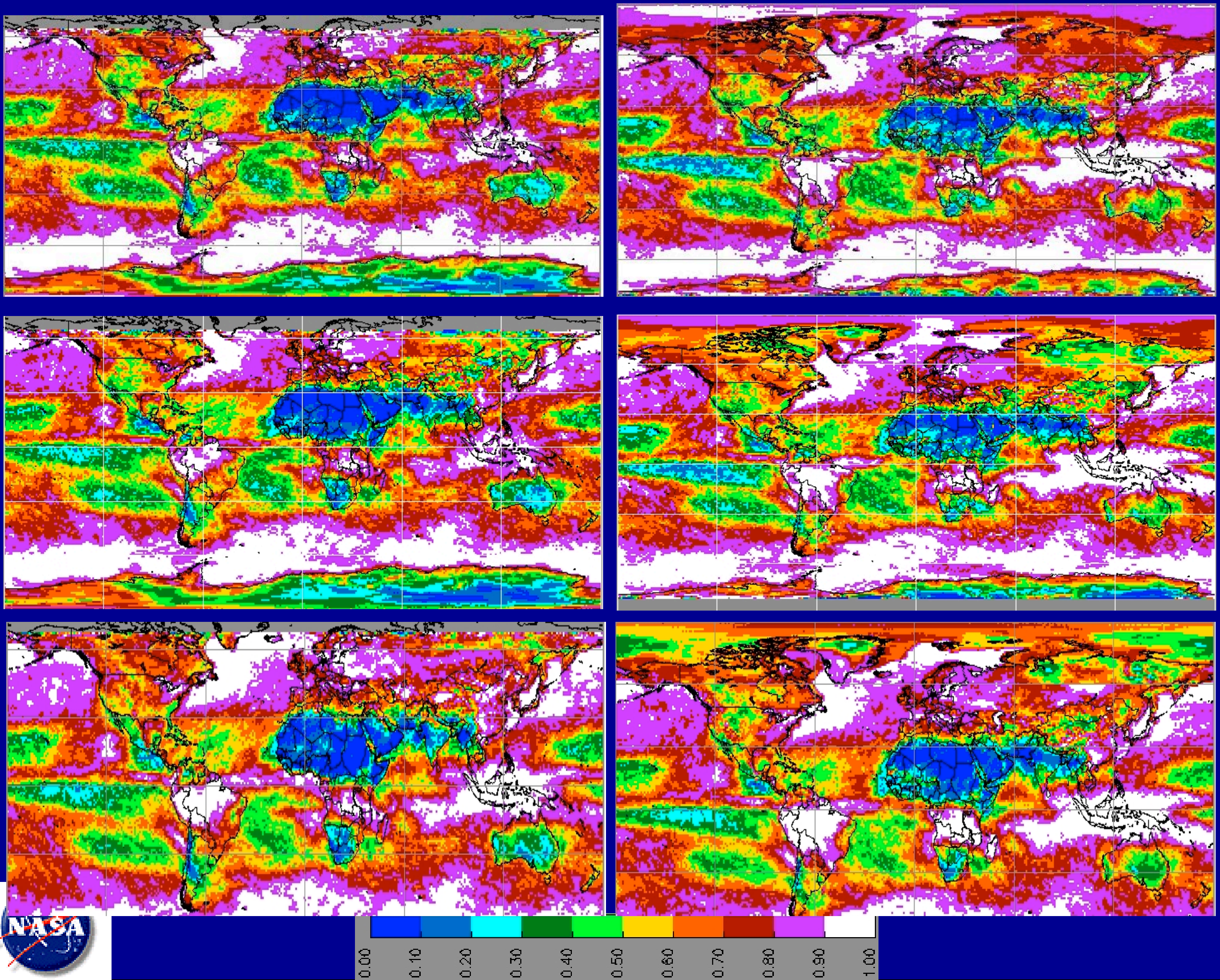


- Polar algorithm line less obvious or missing altogether in new del3
- Cloud cover has noticeably increased (6.9 & 6.8%)

Terra Jan 2001

Daytime

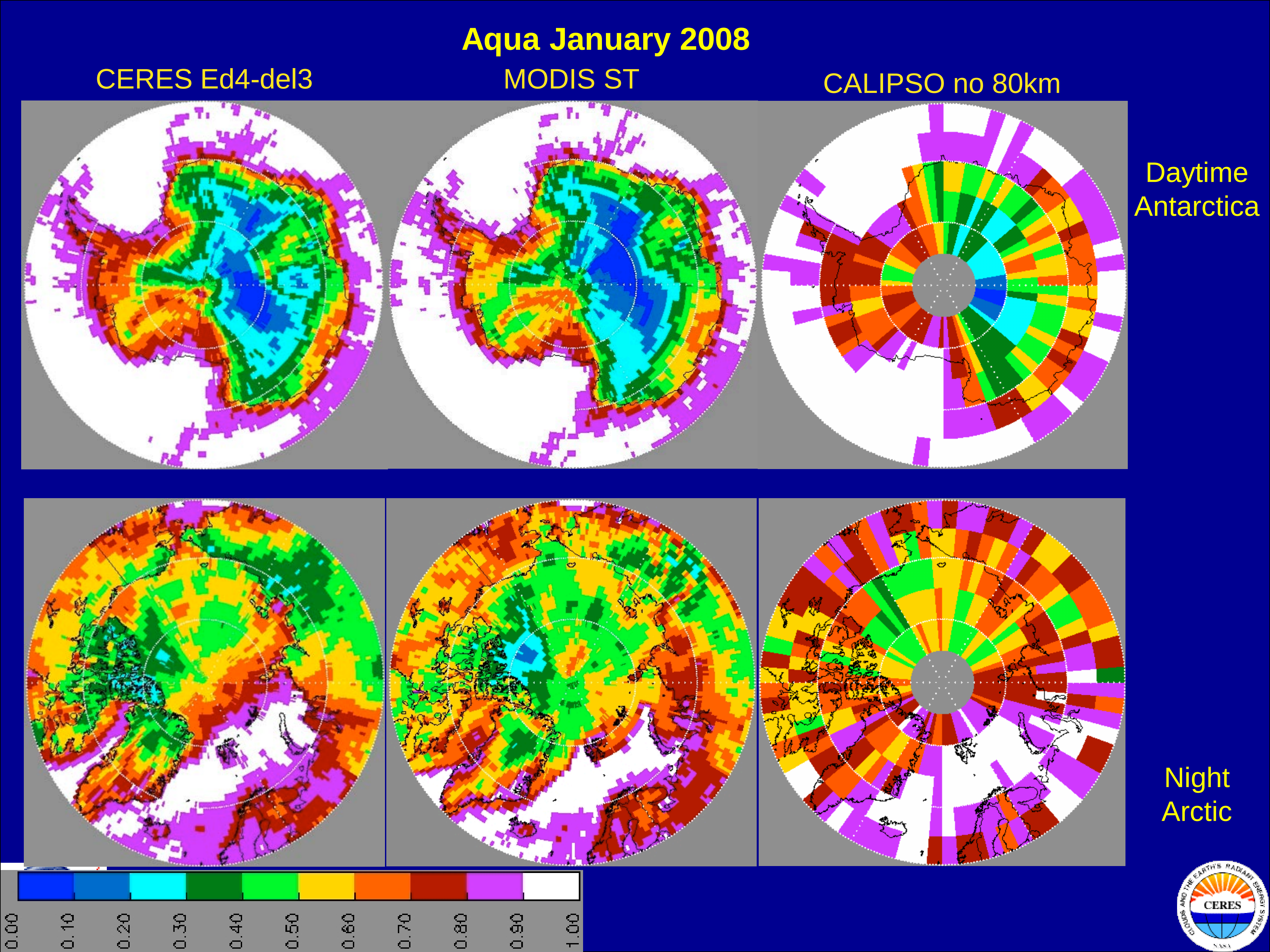
Nighttime



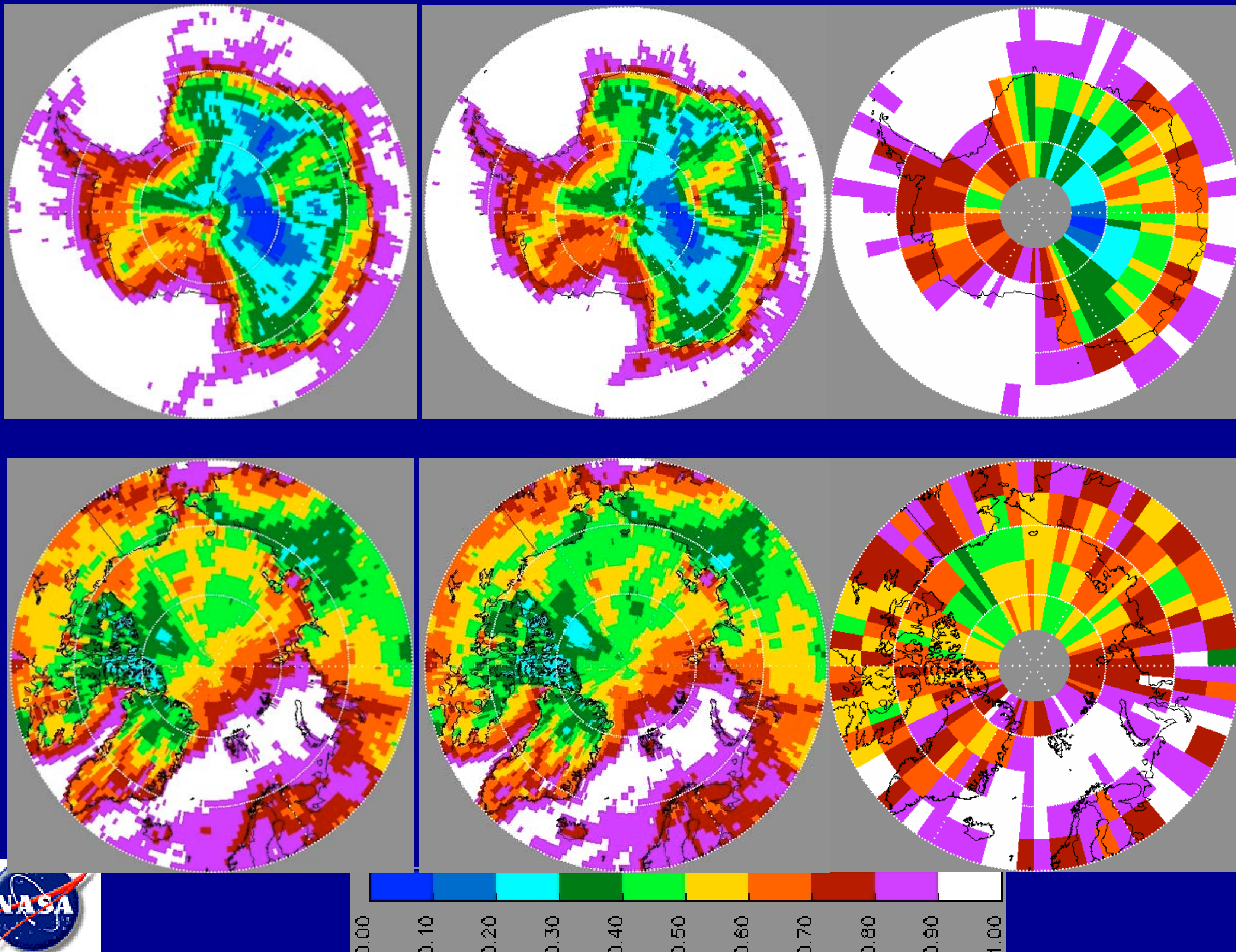
Ed4_Del2
Last Deliver

Ed4_Del3
Final Deliver

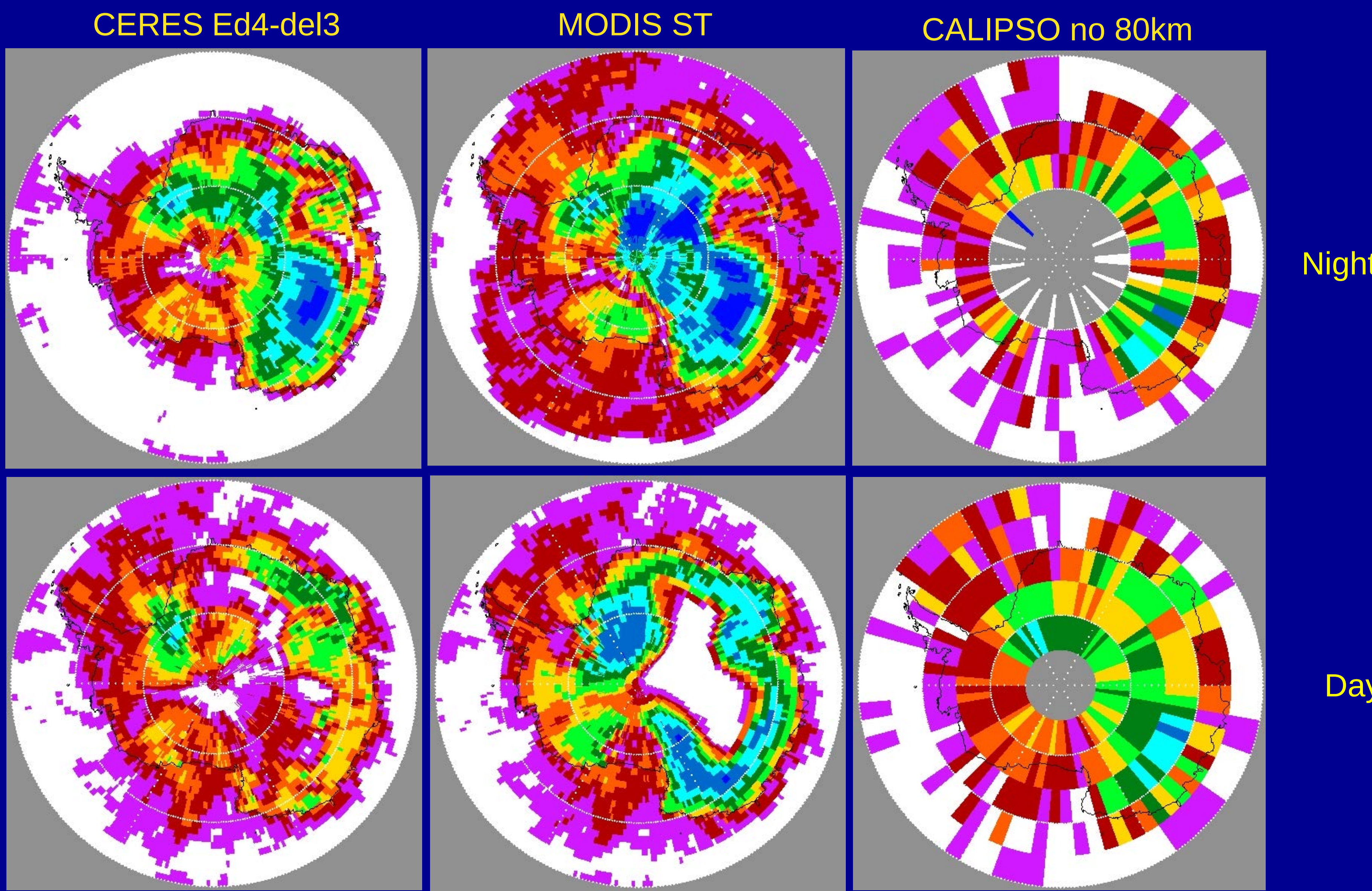
MODIS ST

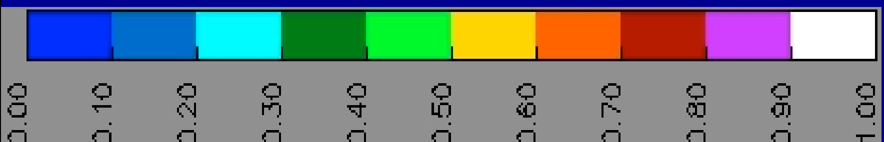

Aqua January 2008
CERES Ed4-del3
MODIS ST
CALIPSO no 80km
Daytime
Antarctica
Night
Arctic
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
CERES

Aqua and Terra January 2008



Aqua October 2008, Antarctica

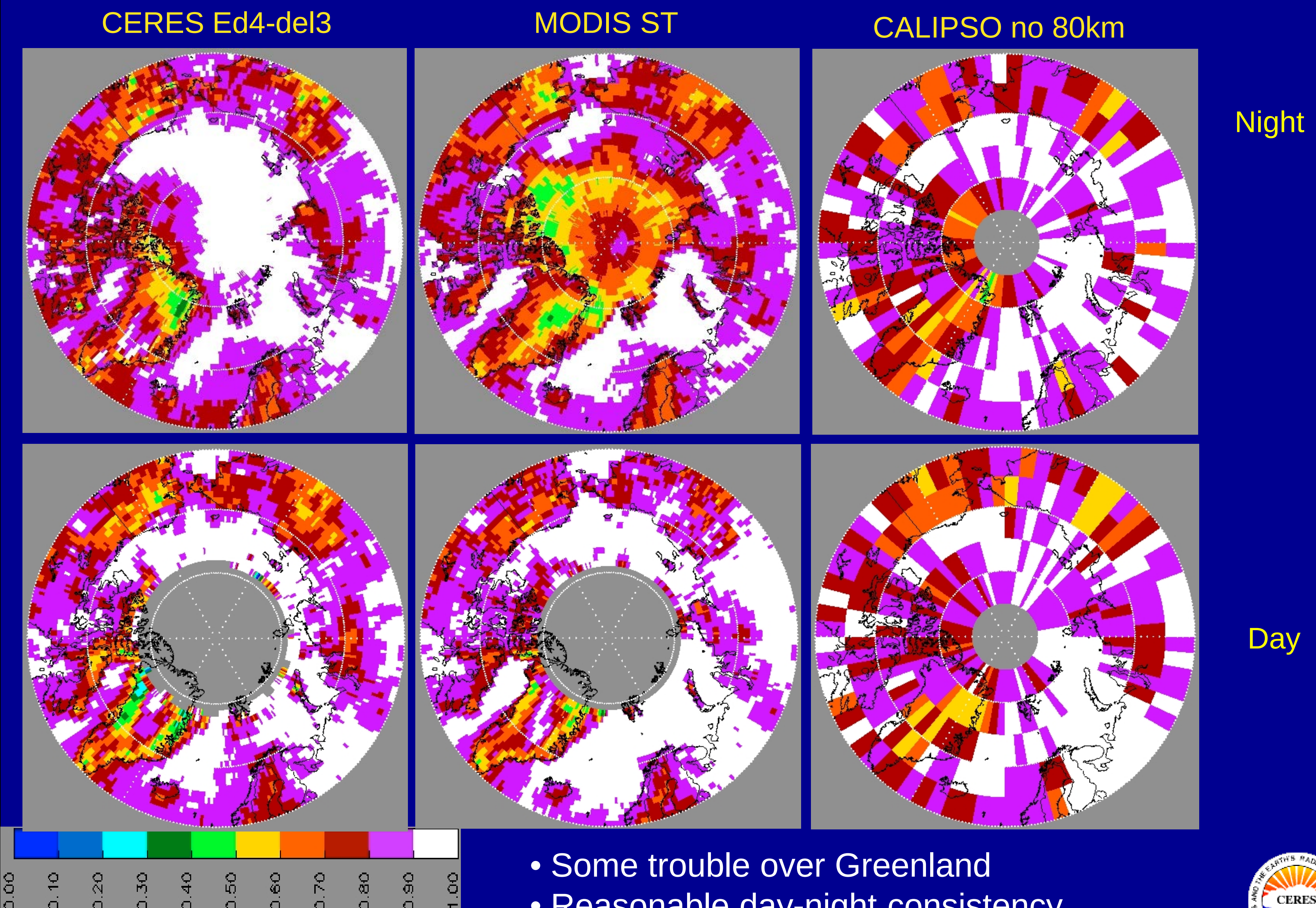




CERES-CAL = 0.027 (Ant)   0.000 (Arc)

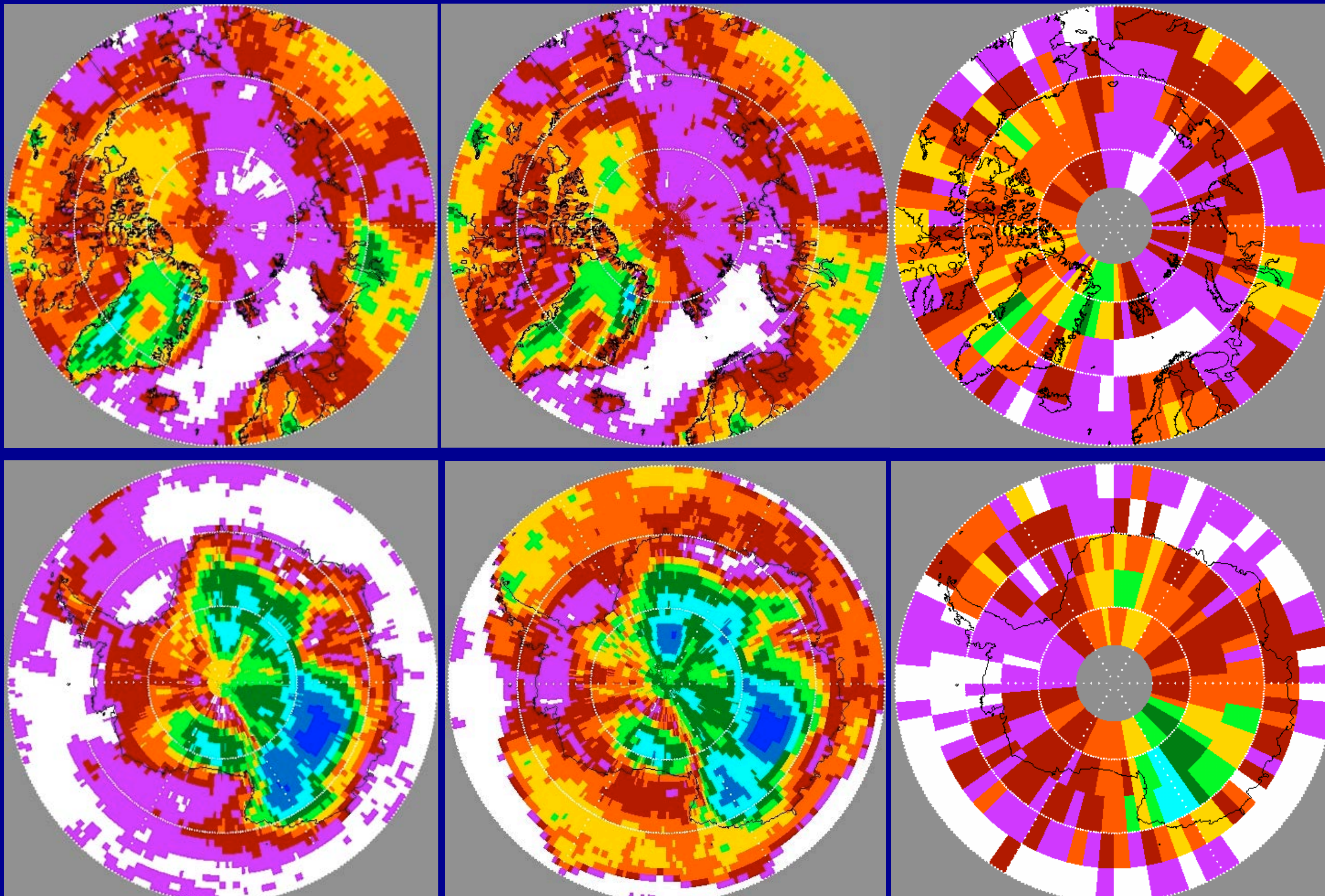
MAST – CAL = 0.000 (Ant) -0.400 (Arc)

Aqua October 2008



- Some trouble over Greenland
- Reasonable day-night consistency

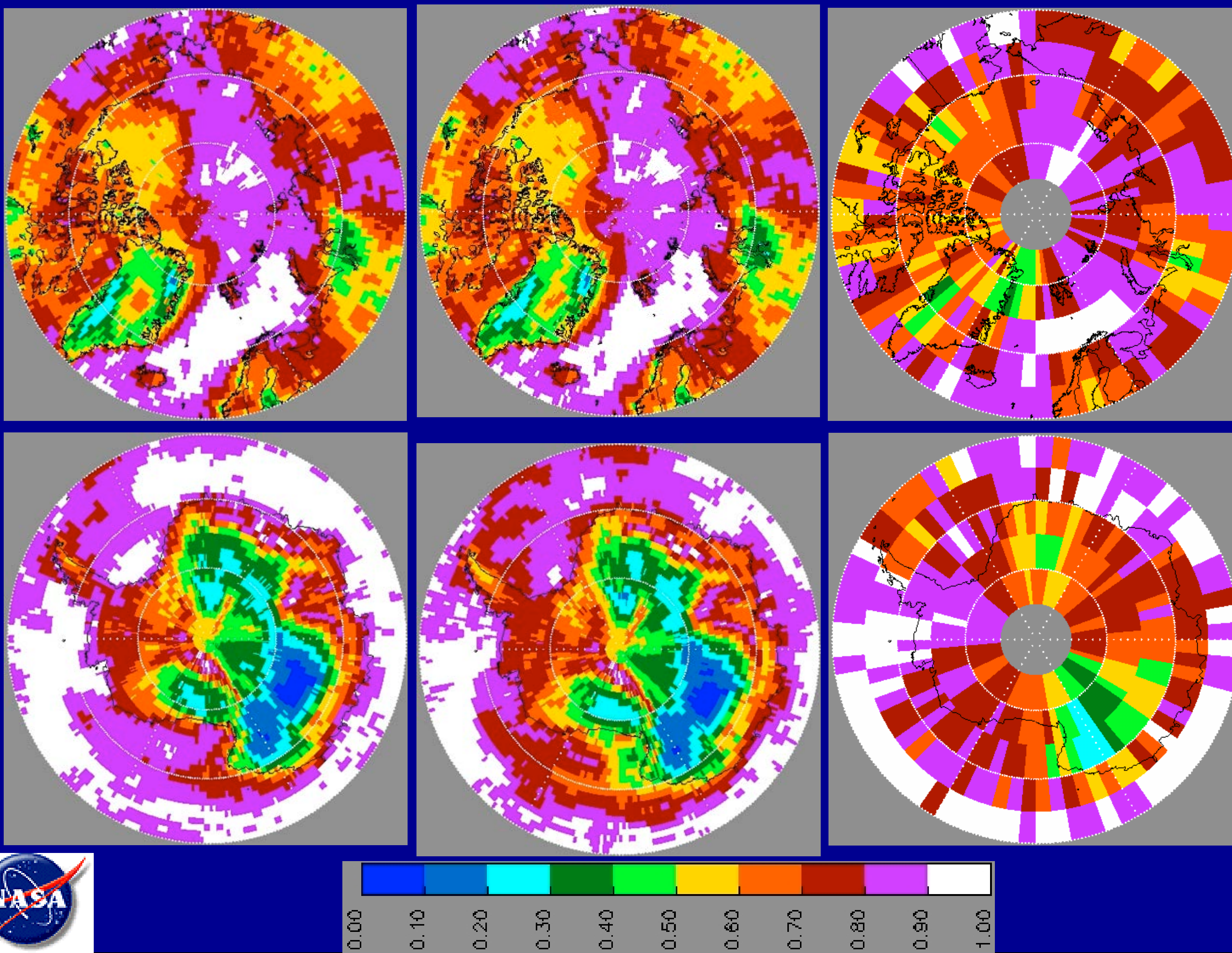
Aqua July 2008



- Maybe too little over Antarctica
- Overall quite good during daytime

Aqua and Terra July 2008

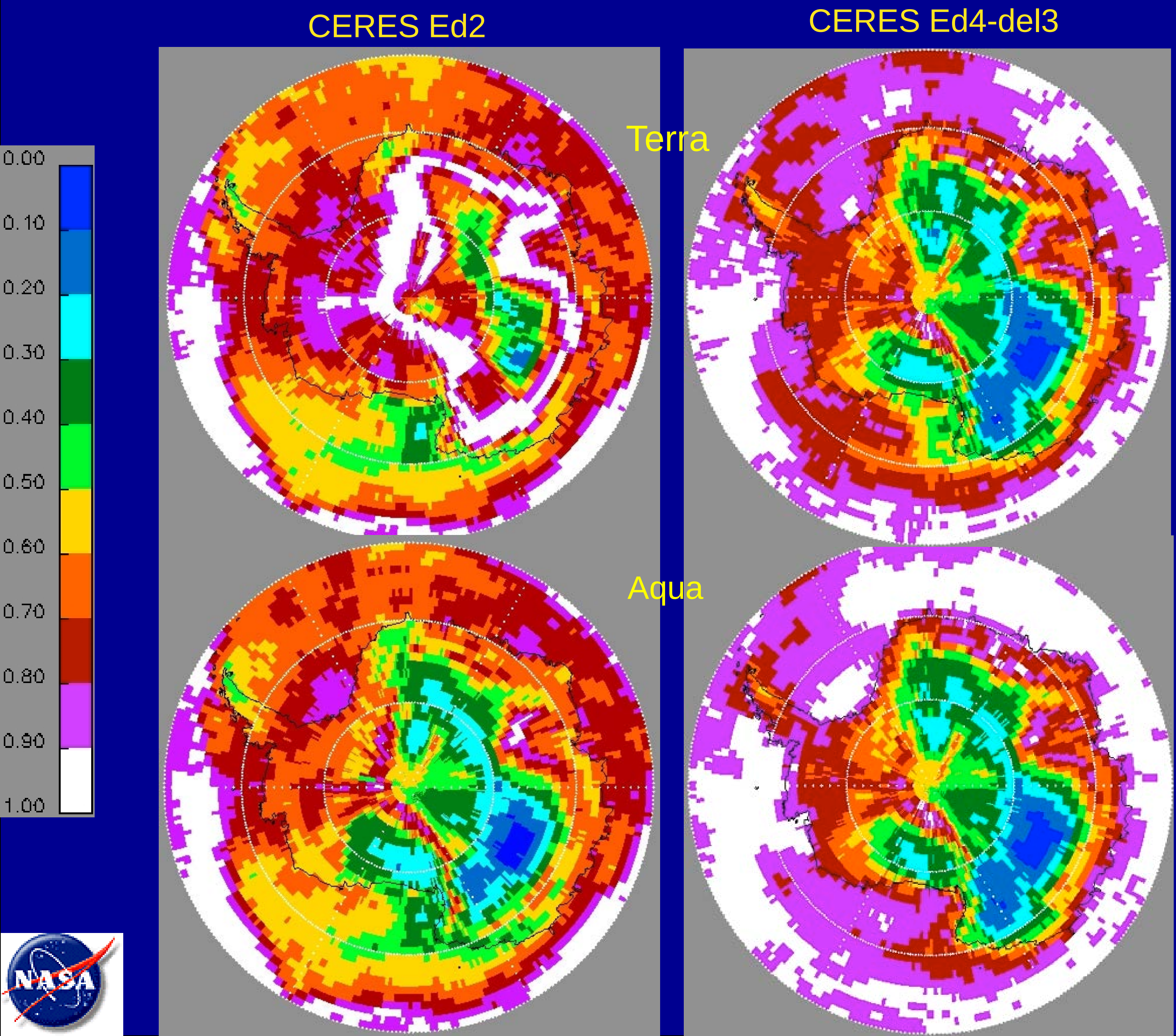
CERES Aqua Ed4-del3 | CERES Terra Ed4-del3 | CALIPSO no 80km



Day
Antarctica

Night
Arctic

Aqua and Terra July 2008 Night, Antarctica

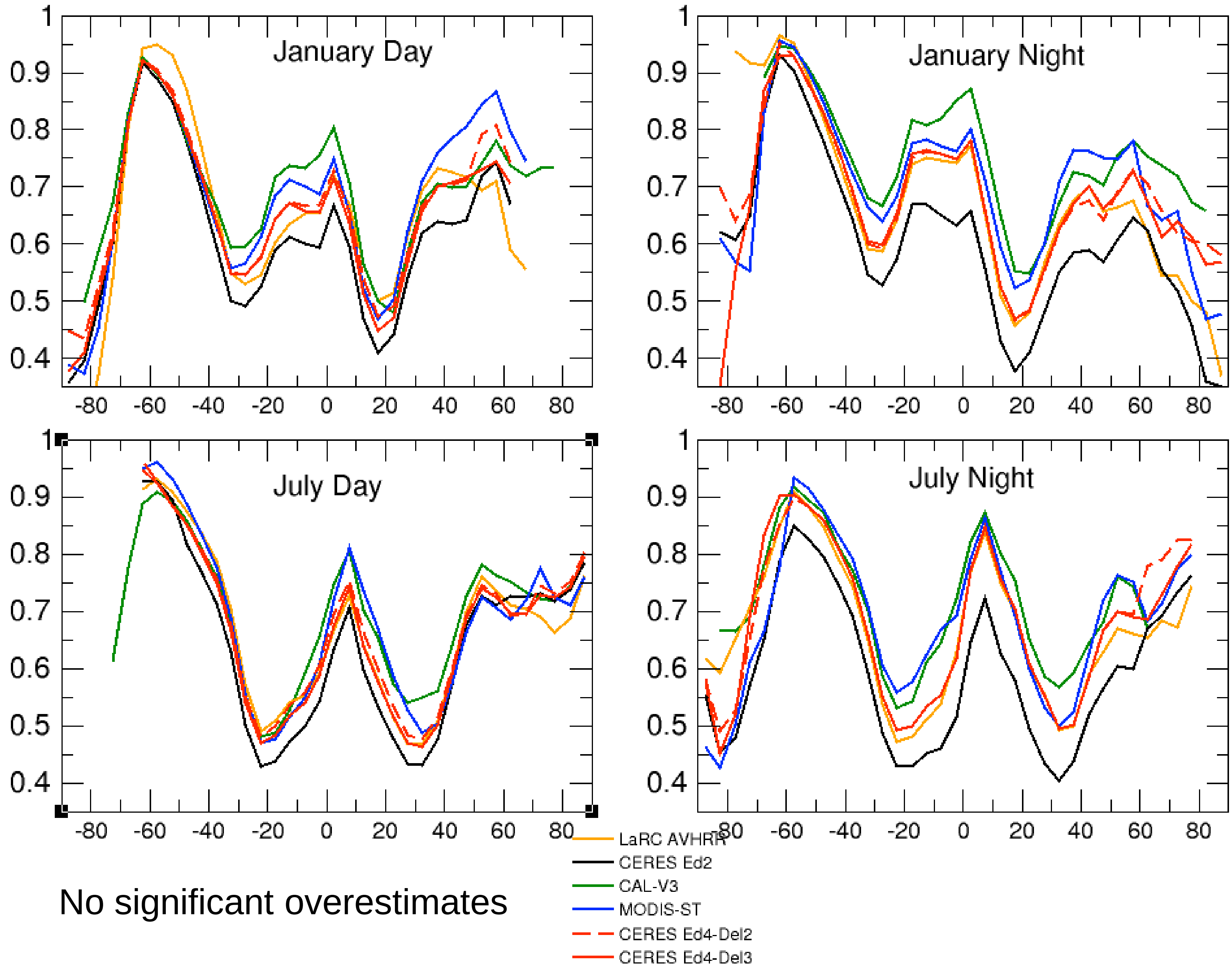


Terra & Aqua more consistent now over Antarctica

3.7-µm calibrations worked well

Zonal Cloud Fraction, Aqua 2008

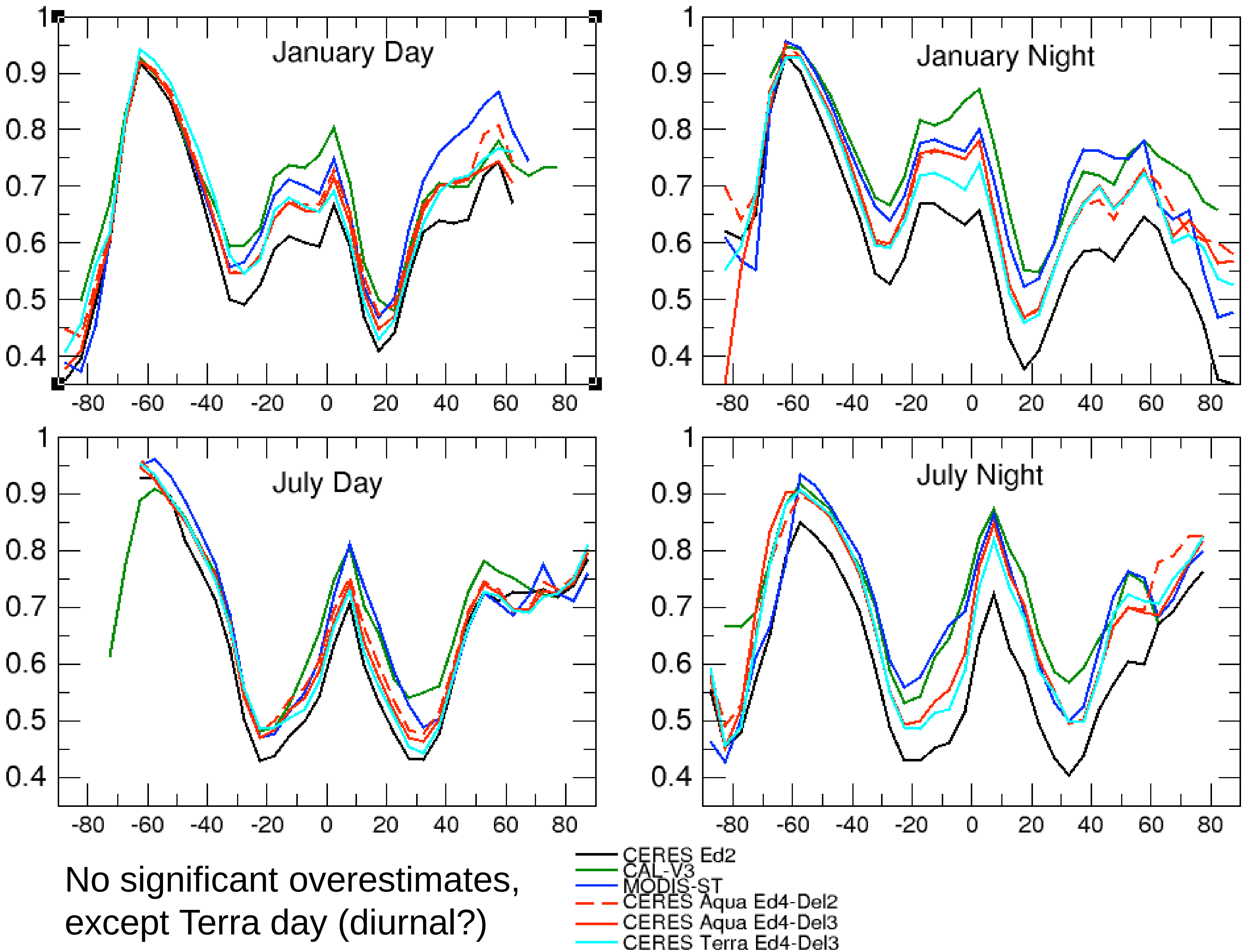
CERES Ed4 & Ed2, AVHRR, MODIS ST, CALIPSO V3 VFM



No significant overestimates

Zonal Cloud Fraction, Aqua 2008

CERES Ed4 & Ed2, Terra Ed4, MODIS ST, CALIPSO V3 VFM



No significant overestimates, except Terra day (diurnal?)

Global Cloud Fraction Comparison
January and July 2008

	January Day	July Day	January Night	July Night
Aqua Ed4-Del3	0.651	0.667	0.673	0.667
Terra Ed4 -Del3	0.661	0.662	0.667	0.669
Aqua Ed2	0.611	0.644	0.604	0.580
LaRC AVHRR	0.638	0.671	0.680	0.667
MODIS-ST	0.682	0.687	0.701	0.686
CALIPSO No 80km	**0.699**	**0.694**	**0.753**	**0.715**

- Total cloud cover has risen by 0.04 – 0.09
- Aqua & Terra more consistent than Ed2
- Day-night more consistent

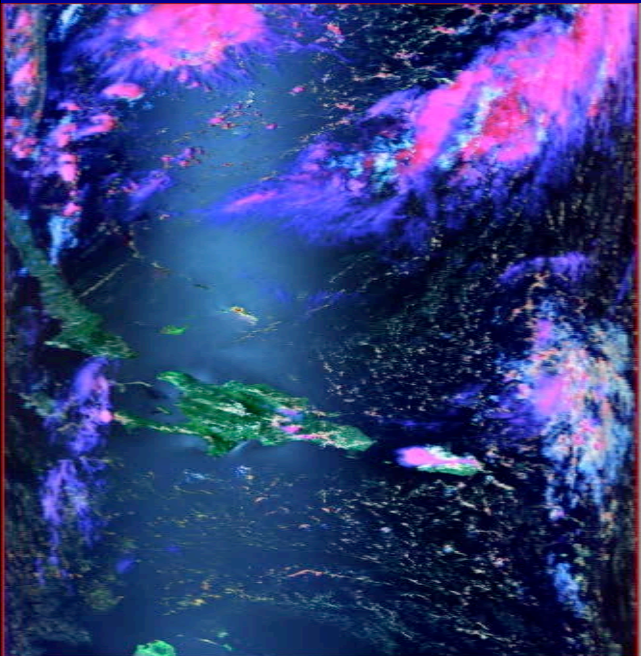
Changes in Multilayer Cloud Processing

- Last delivery: Unit errors caused RH≥100% in all CO2 & ML retrievals.
- CO2, IR, near-IR channel transmittance calculations were all affected.
- Reset input parameters to correct RH unit: underestimation => overestimation.
- Changes:
  Redefined threshold/sensitivity criteria for CO2 & ML detections/retrievals.

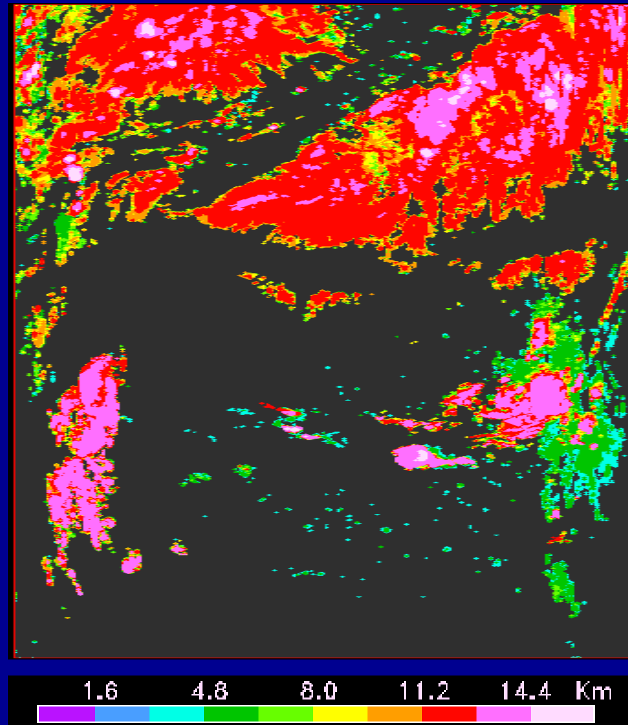
Results:

- CO2:
  Improved cirrus detection and height retrieval.
  Improved cirrus emissivity retrieval and optical depth calculation.
- ML:
  Improved ML detection and retrieval.
  Upper layer emissivity and optical depth has decreased significantly.
  Upper layer emissivity threshold for ML is reduced from 0.90 to 0.75.
  Lower layer height is changed from climatology to retrieval value,
  Upper layer De changed to Dge. Retrieved value has increased due to RH correction & previous error in Re/De conversion.
  Lower layer r_e still uses running-mean water r_e value saved in common block.
- Daytime and Nighttime:
  Nighttime ML climatology resembles daytime ML climatology with corrected upper layer optical depths.

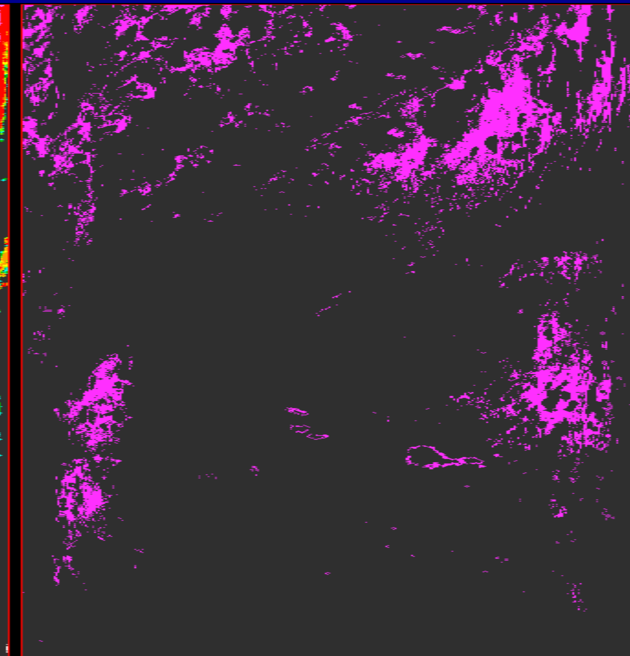
Aqua 2007.07.30.1800



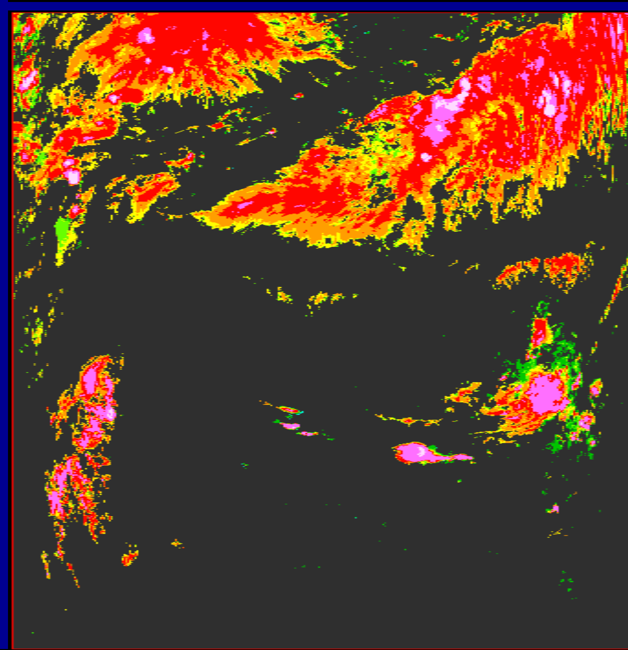
CO_2 Cloud Height

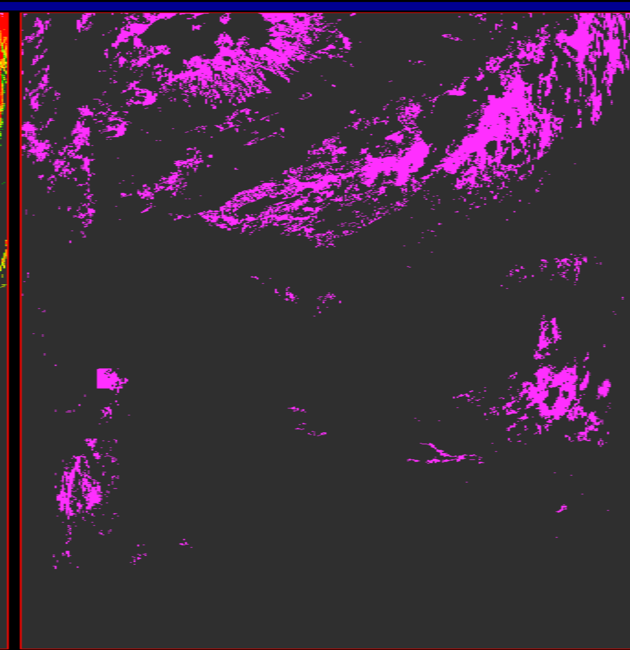


Multilayer ID

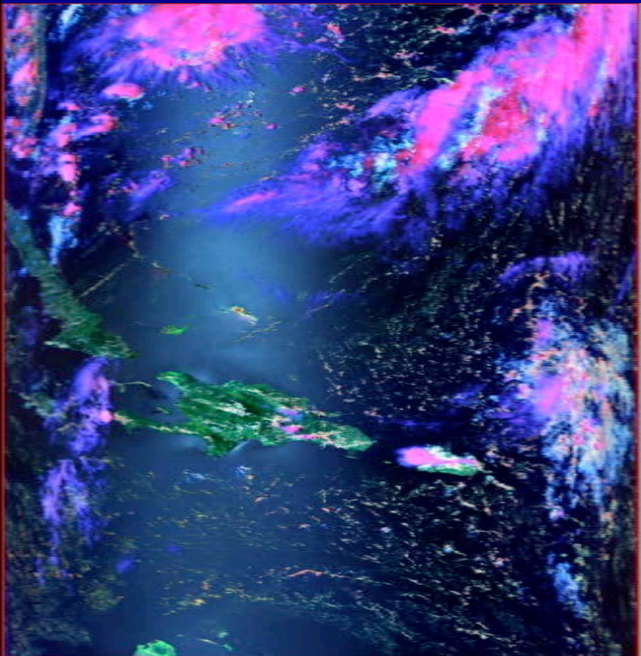


Last delivery =>



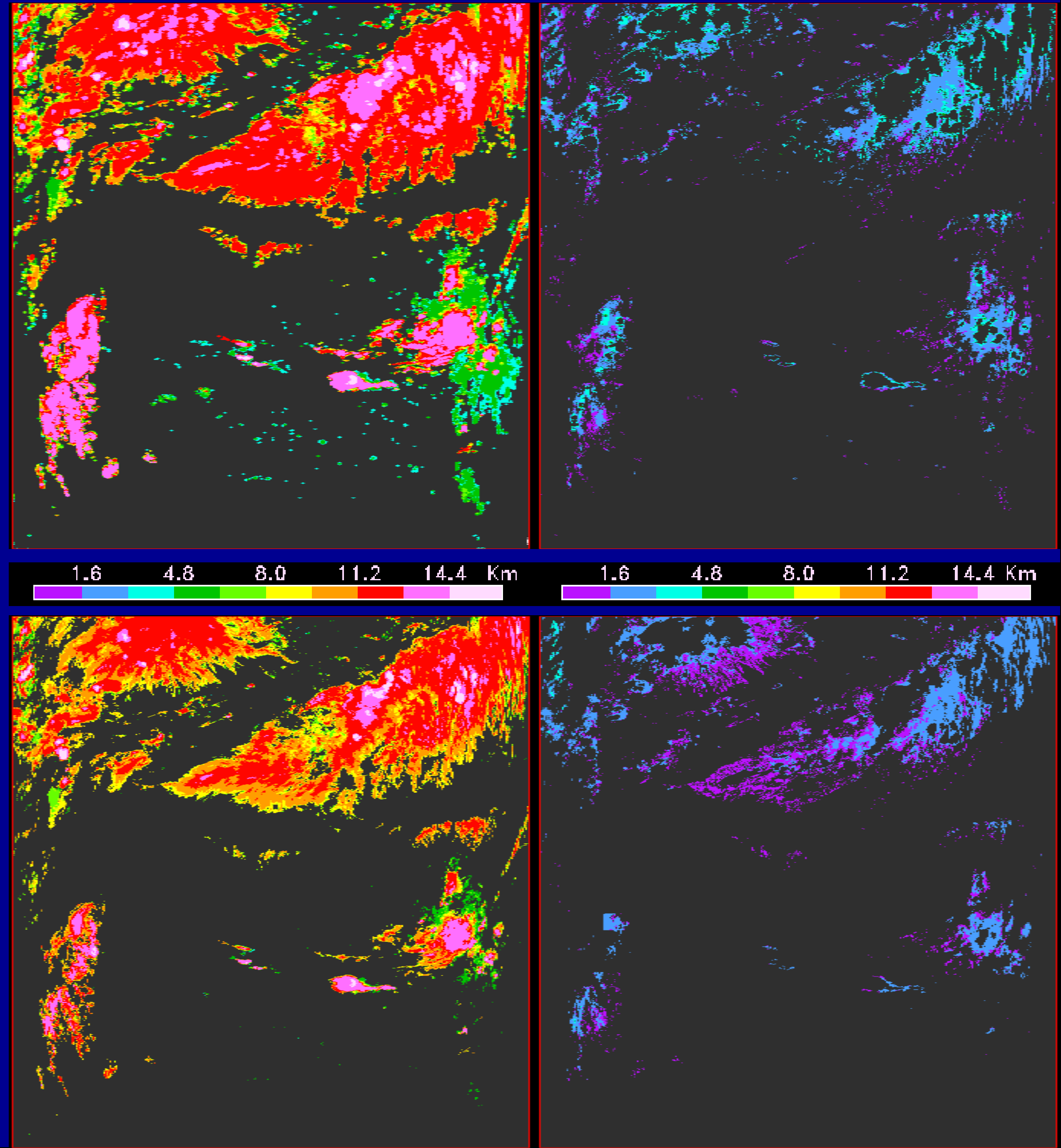


Aqua 2007.07.30.1800



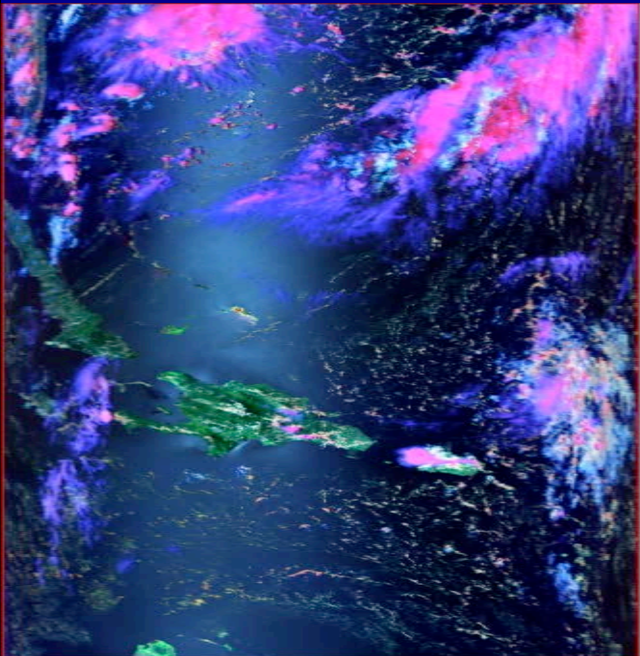
Upper Layer Height

Lower Layer Height

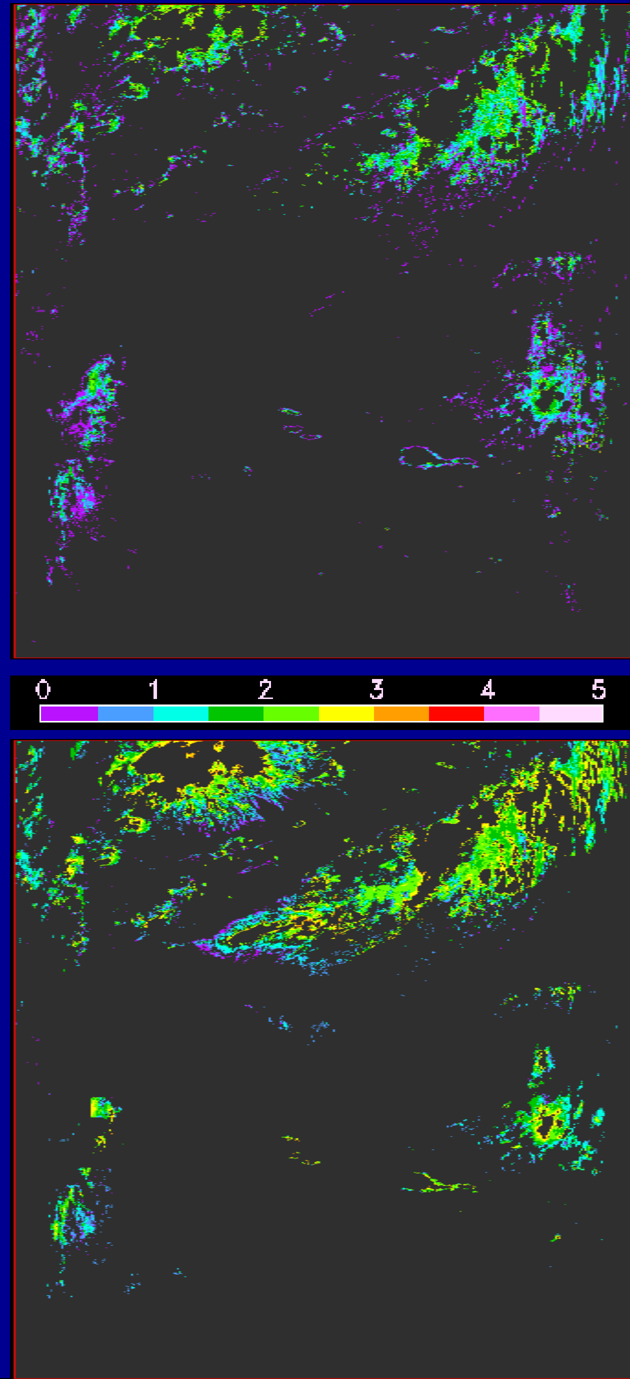


Last delivery =>

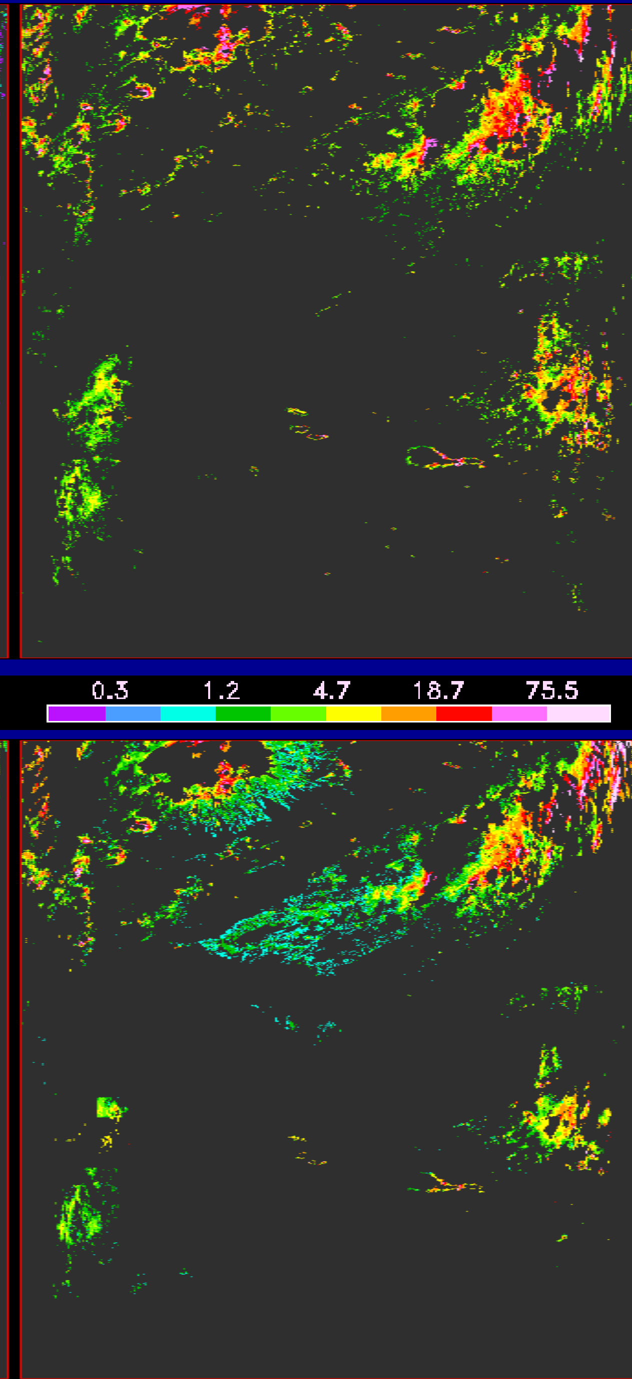
Aqua 2007.07.30.1800



ML Upper Optical Depth

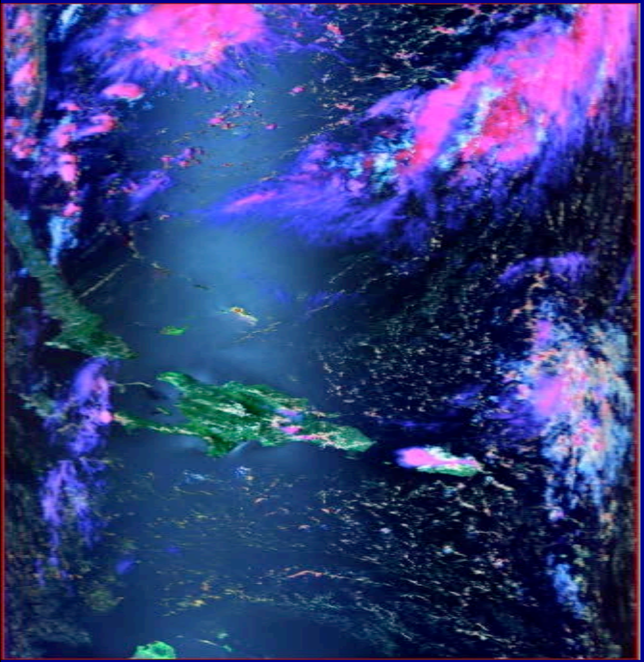


ML Lower Optical Depth



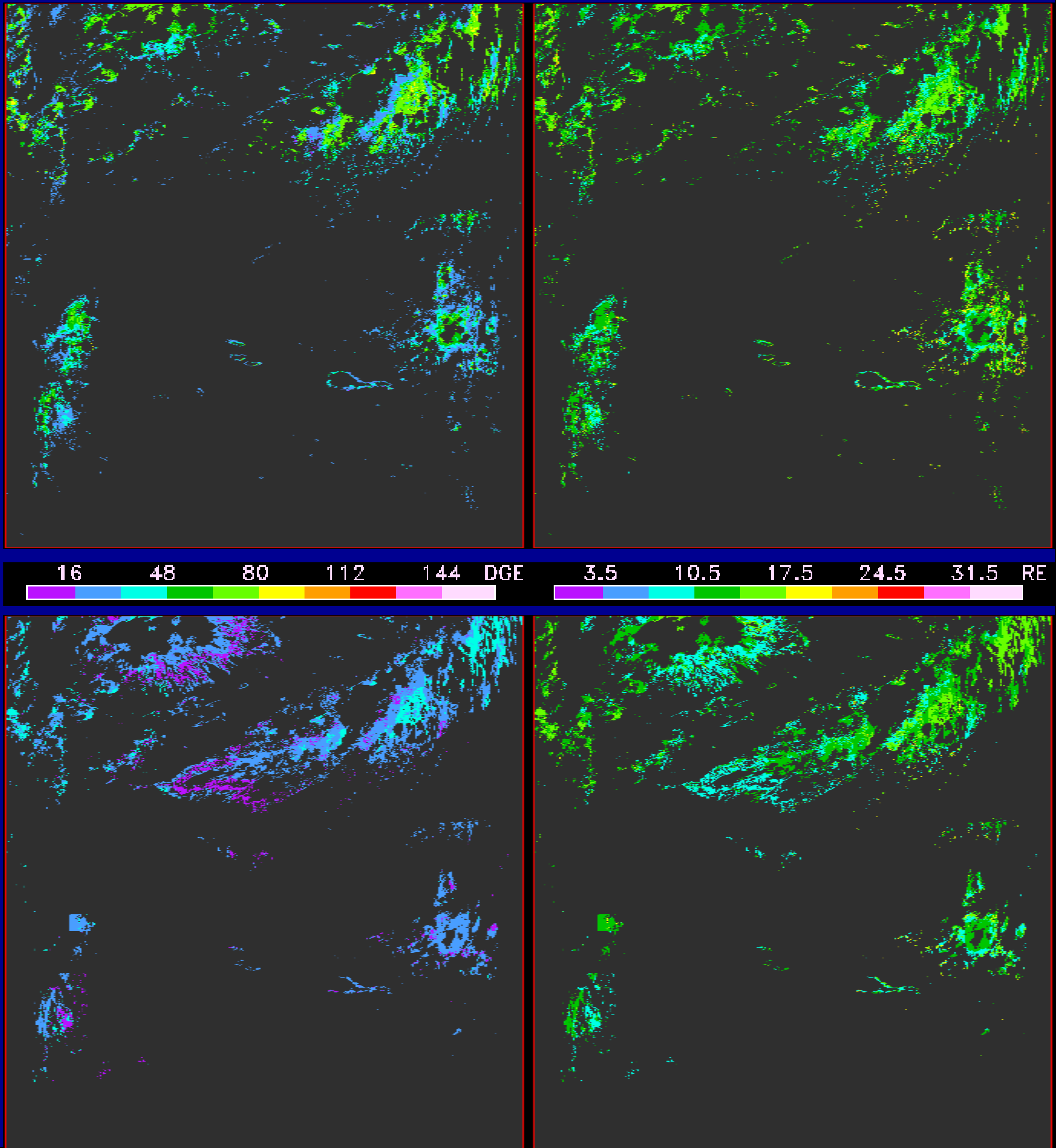
Last delivery =>

Aqua 2007.07.30.1800



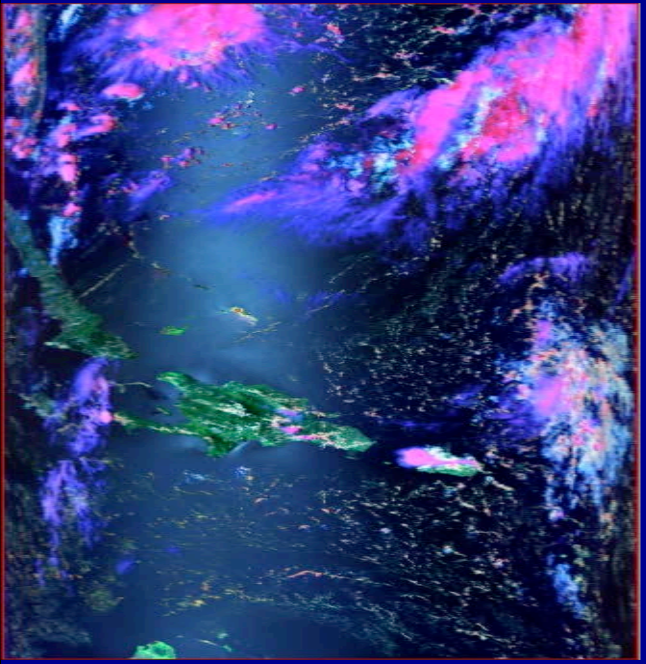
ML Upper Dge(3.7μm)

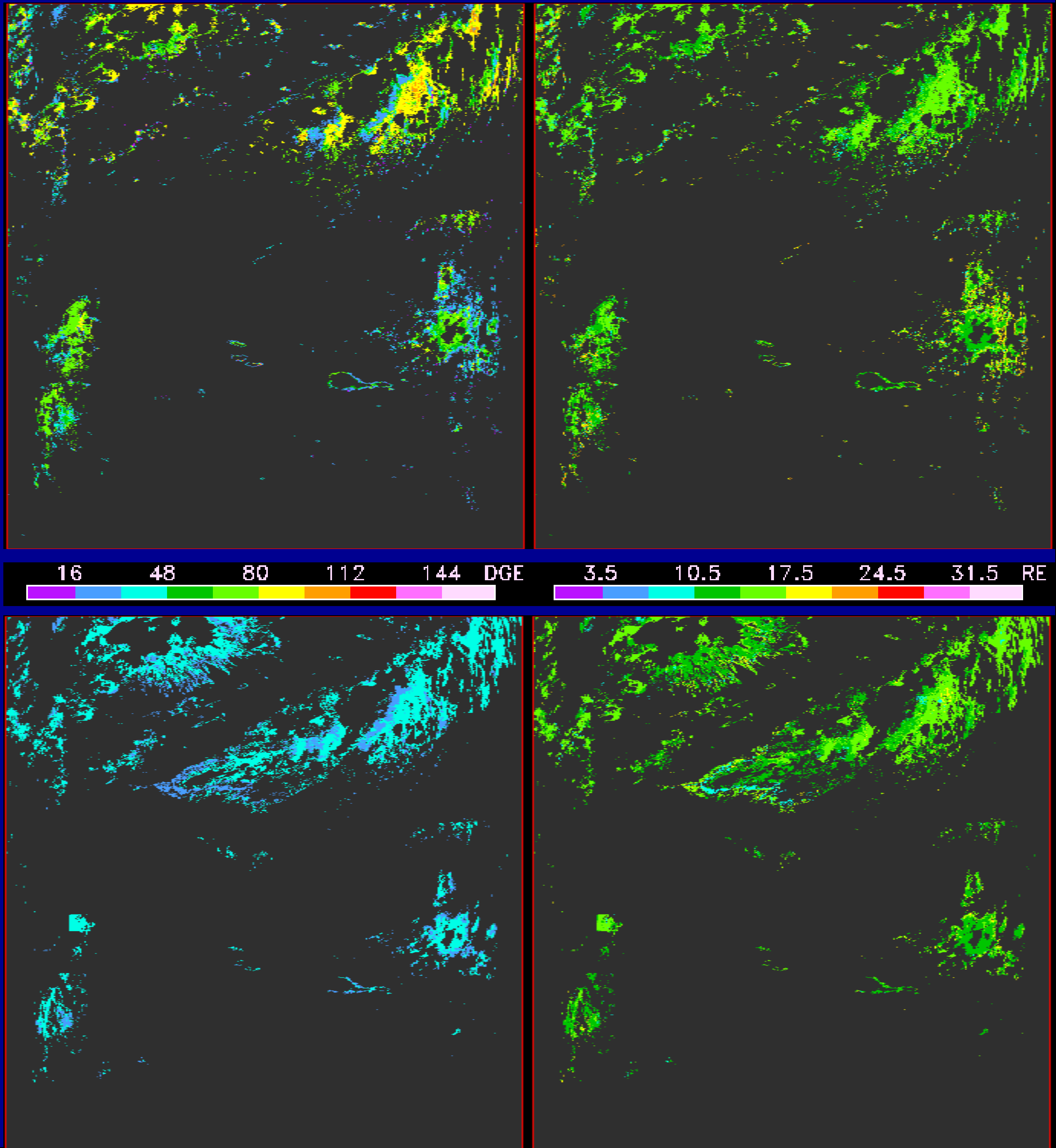
ML Lower r_e (3.7μm)



Last delivery =>

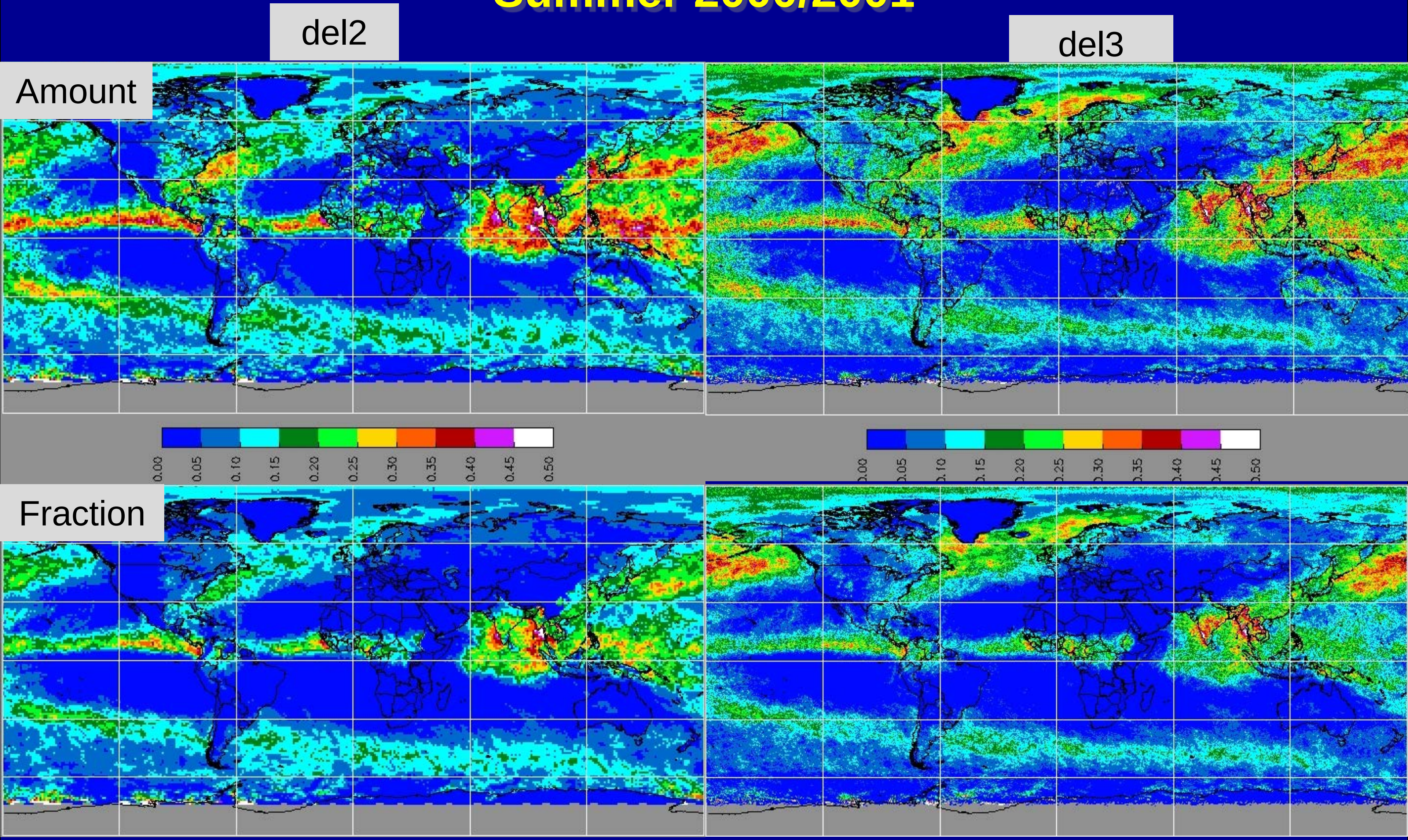
Aqua 2007.07.30.1800 | ML Upper Dge(2.1μm) | ML Lower r_e (2.1μm)





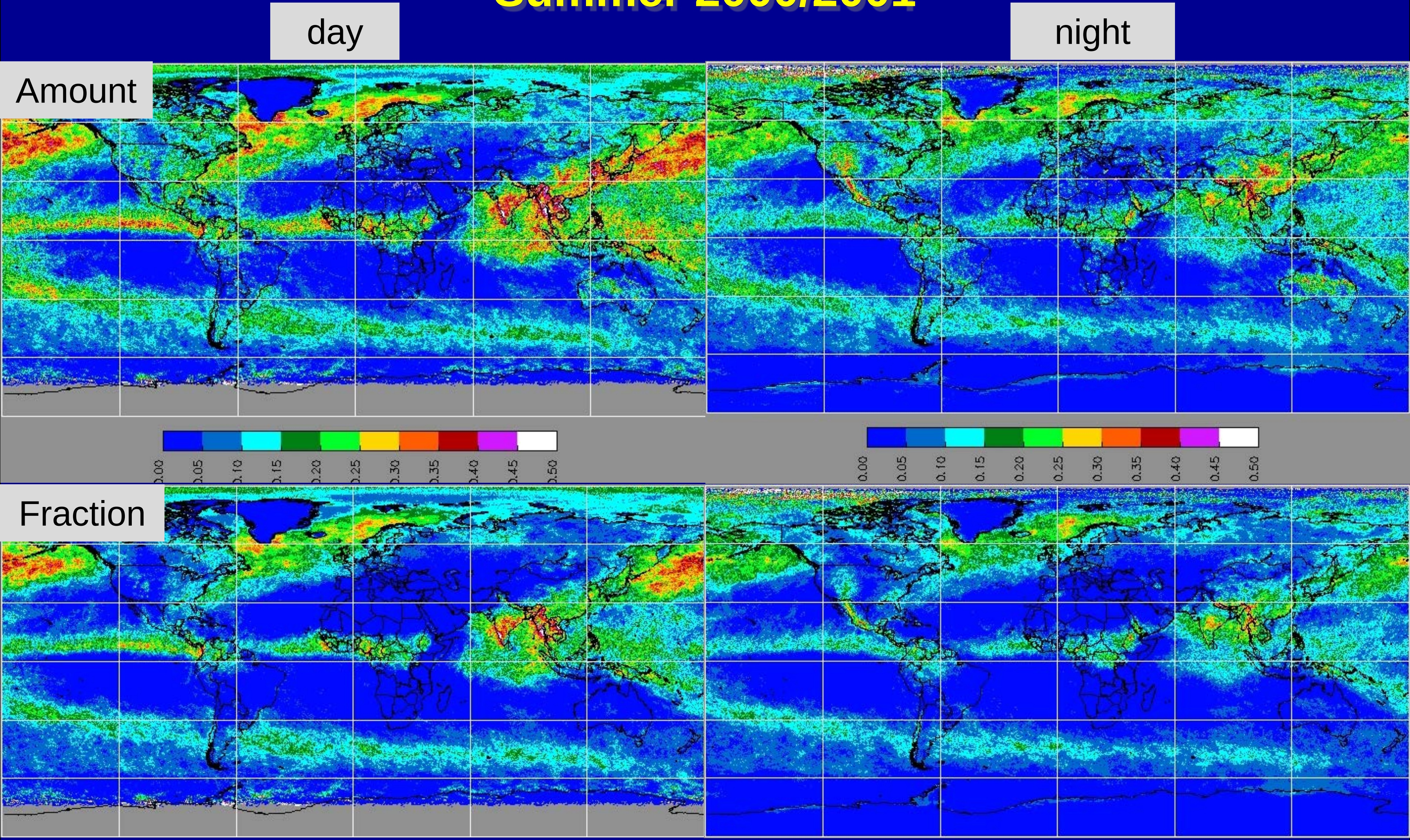
Last delivery =>

Daytime Multilayered Cloud Amounts & Heights
Summer 2000/2001



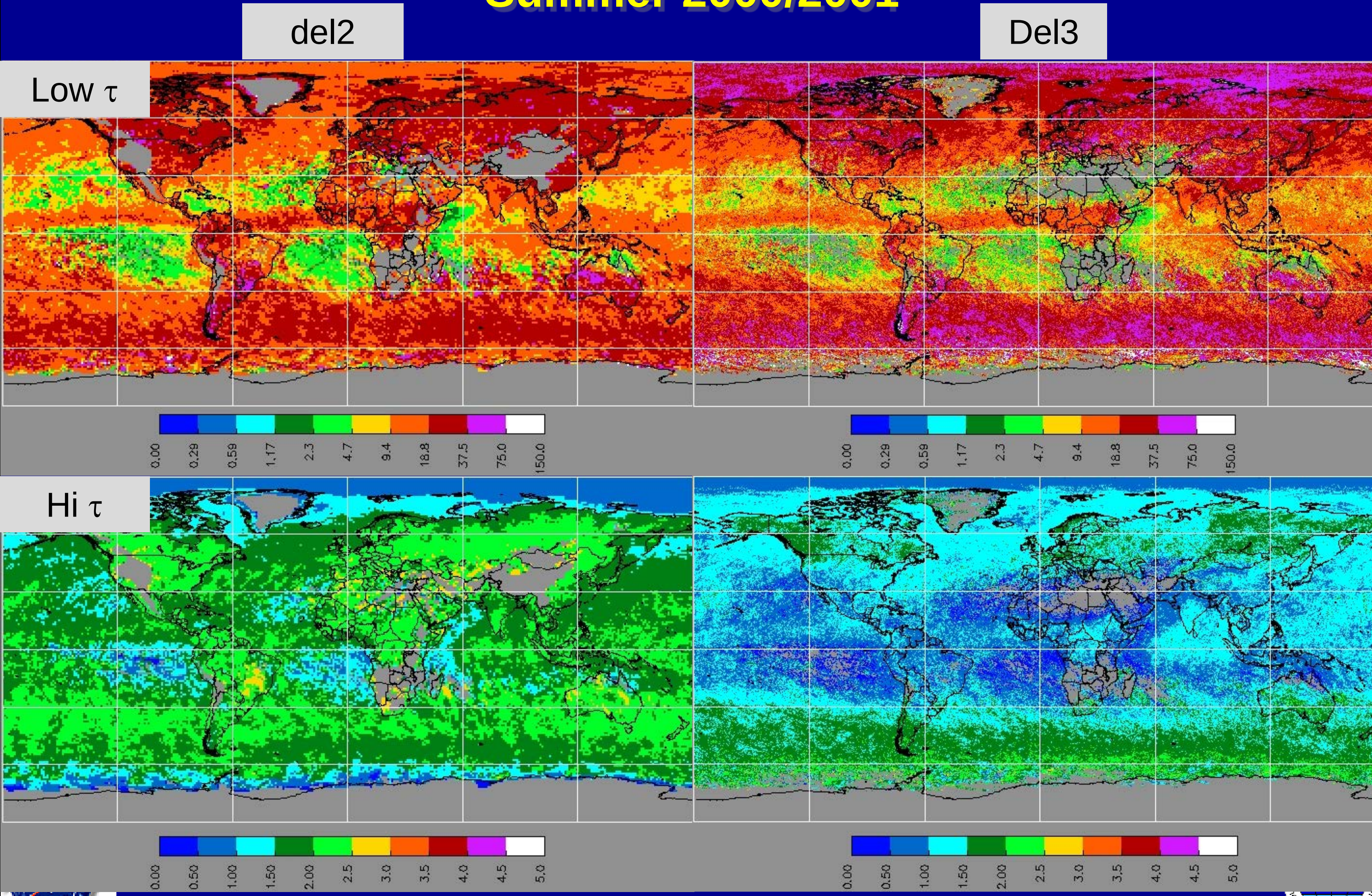
• del3 picking up more in mid-latitudes, less in tropics

Day-Night Multilayered Cloud Amounts & Heights Summer 2000/2001

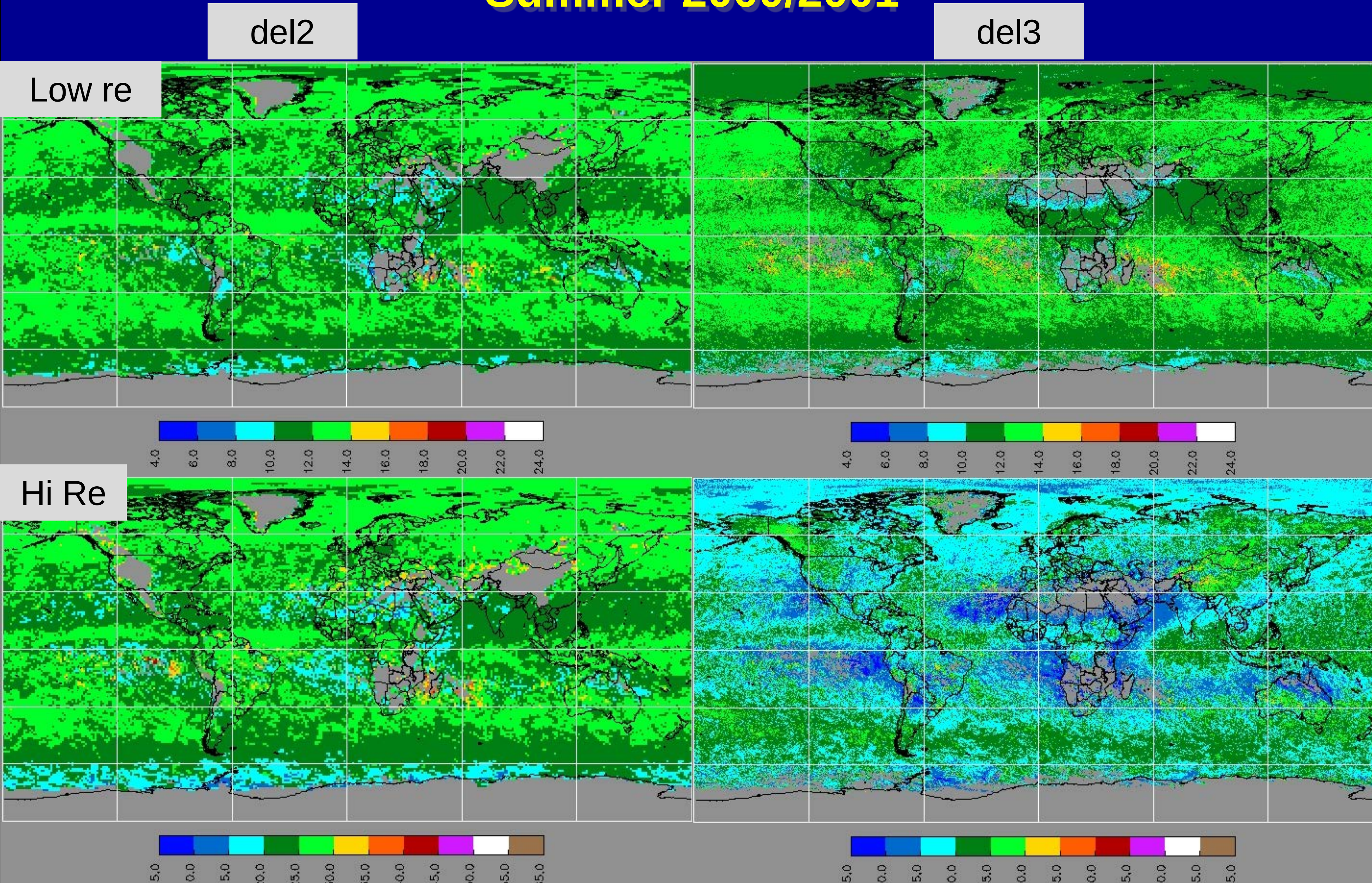


- night-day patterns very similar, reduced fraction at night

Daytime Multilayered Particle Size & Optical Depth Summer 2000/2001



Daytime Multilayered Particle Size & Optical Depth Summer 2000/2001



The Blue Marble

Human's view of Earth

<u>True Color RGB</u>

Terra MODIS

from Stöckli et al.

The Blue Marble

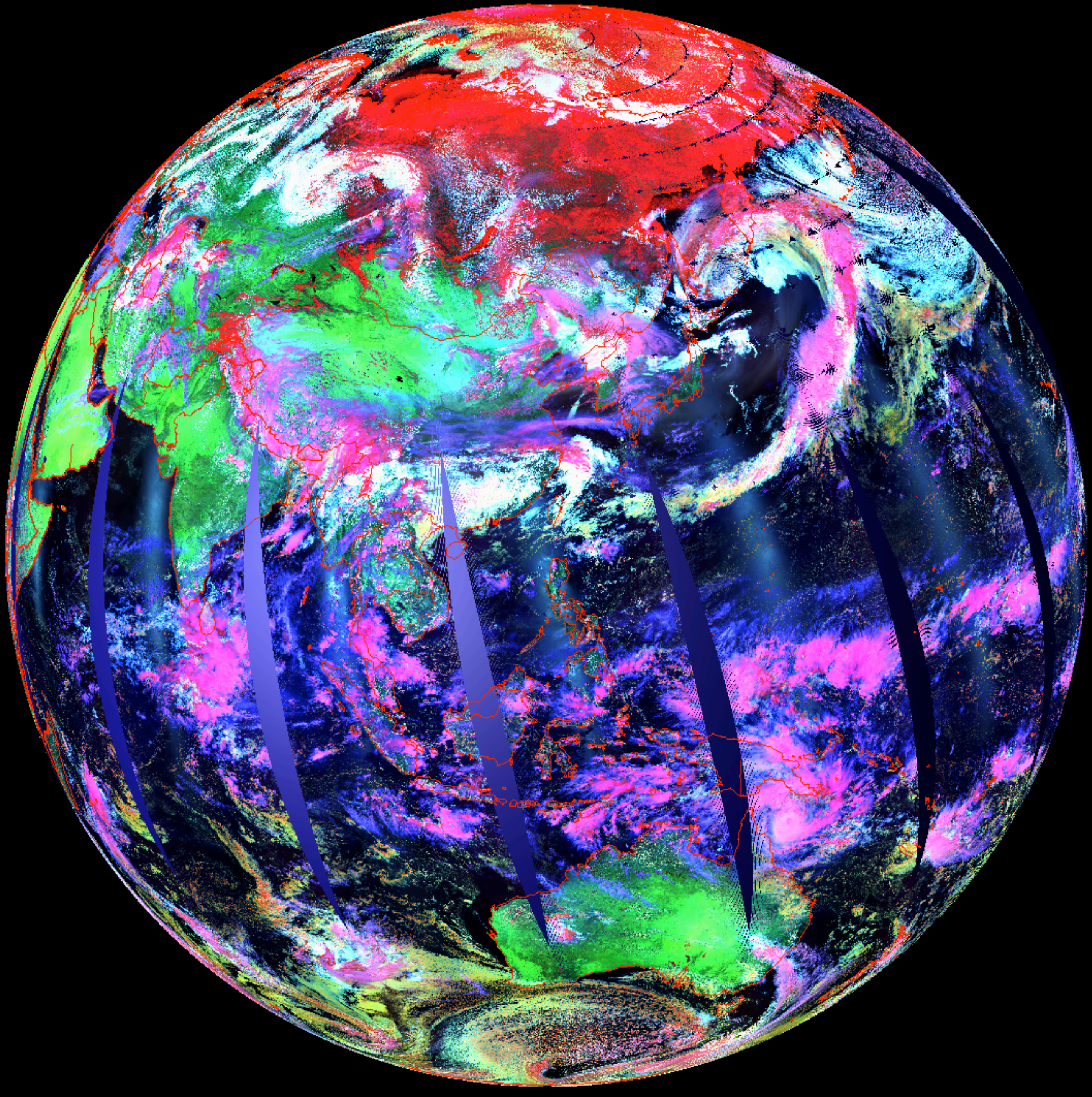
True Color RGB

Terra MODIS

from Stöckli et al.

The Unblue Marble

Cloud remote sensing view of Earth



Pseudocolor RGB

Red: 0.6 µm

Green: 2.1 µm

Blue: 3.7-11 µm

Aqua
16 April 2006

Sino-centric View

The Unblue Marble

Pseudocolor RGB

Red: 0.6 µm

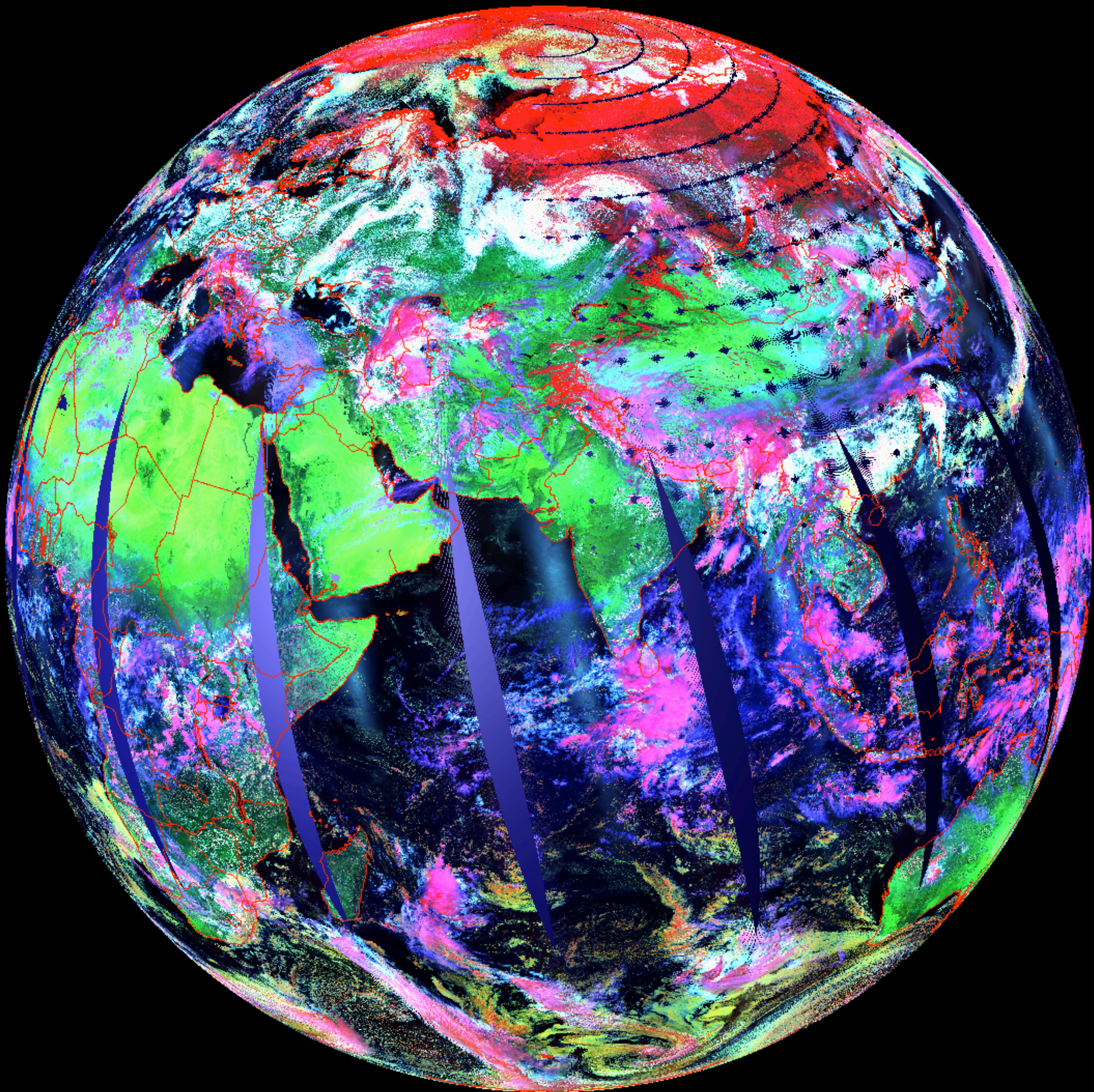
Green: 2.1 µm

Blue: 3.7-11 µm

Aqua

16 April 2006

Indo-centric View



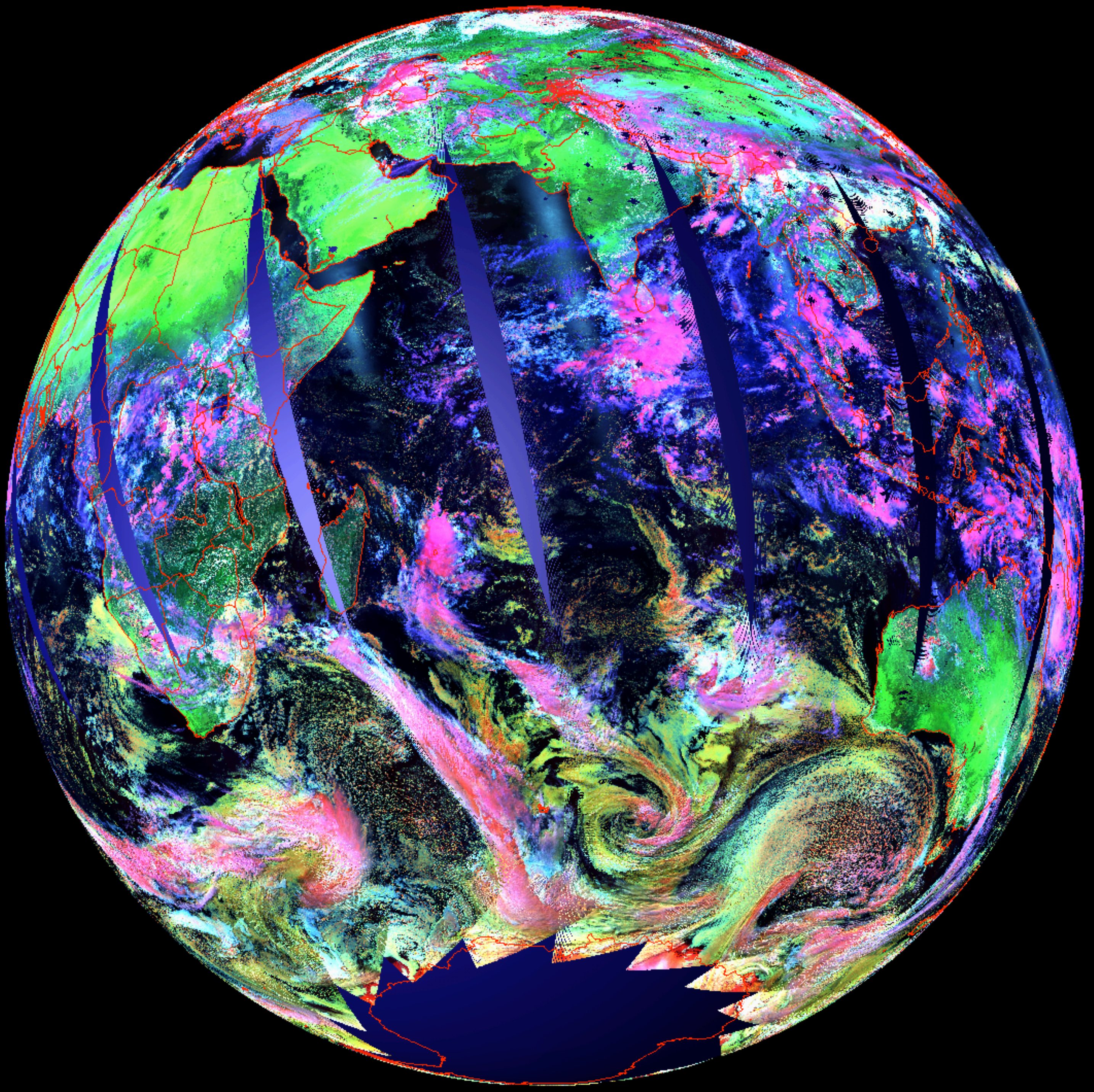
The Unblue Marble

Pseudocolor RGB

Red: 0.6 µm
Green: 2.1 µm
Blue: 3.7-11 µm

Aqua
16 April 2006

Mer-centric View



The Unblue Marble

<u>Pseudocolor RGB</u>

Red: 0.6 µm
Green: 2.1 µm
Blue: 3.7-11 µm

Aqua
16 April 2006

Amer-centric View

The Unblue Marble

Pseudocolor RGB

Red: 0.6 µm
Green: 2.1 µm
Blue: 3.7-11 µm

Aqua
16 April 2006

Arctic-centric View

News

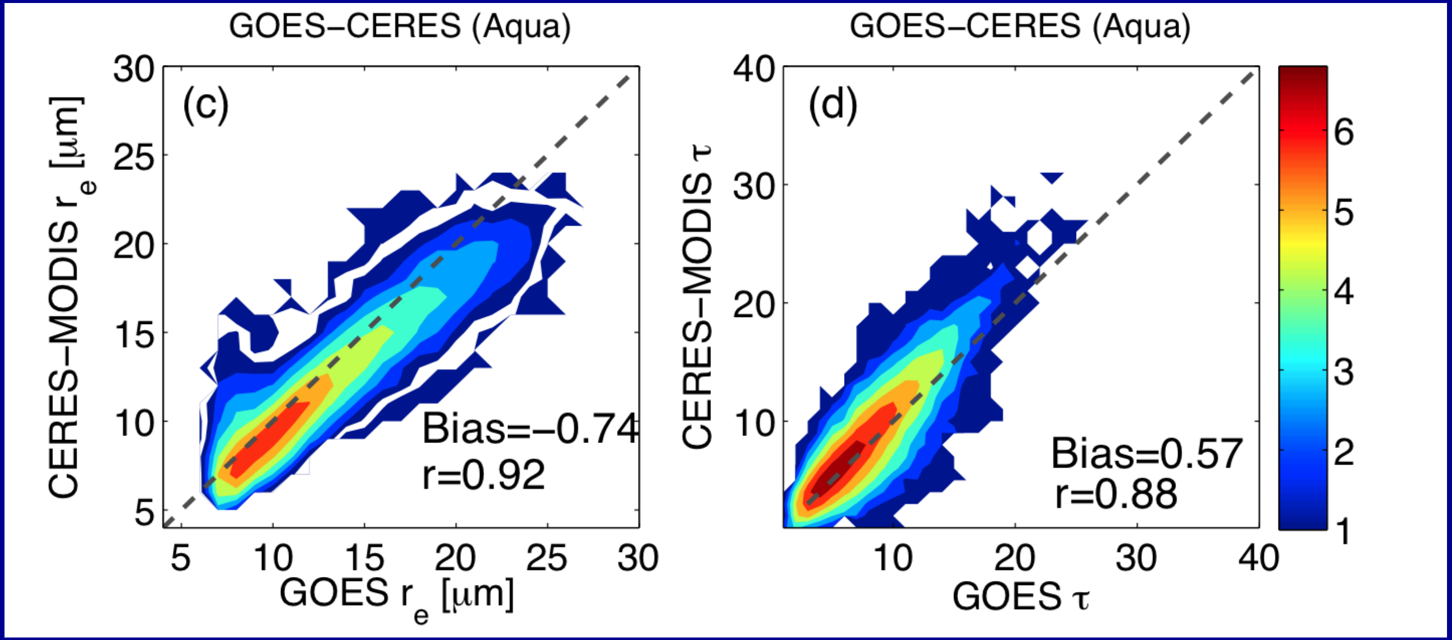
- MODIS Cloud Algorithms Adapted to GEOSat Data for TISA
  - *hourly analyses to be performed (see Palikonda talk)*
  - *excellent agreement for overcast marine strat clouds*

- Getting initial look at VIIRS data & retrievals (*see Sun-Mack talk*)

- Ed4 del3 showing few minor inconsistencies on AMIE-P, resolution in May

Consistency of GOES & **CERES** Aqua Microphysics Retrievals
Marine Stratus, SE Pacific, Oct – Nov 2008

R_e | Opt Depth



RMS = 1.5 µm (13%)

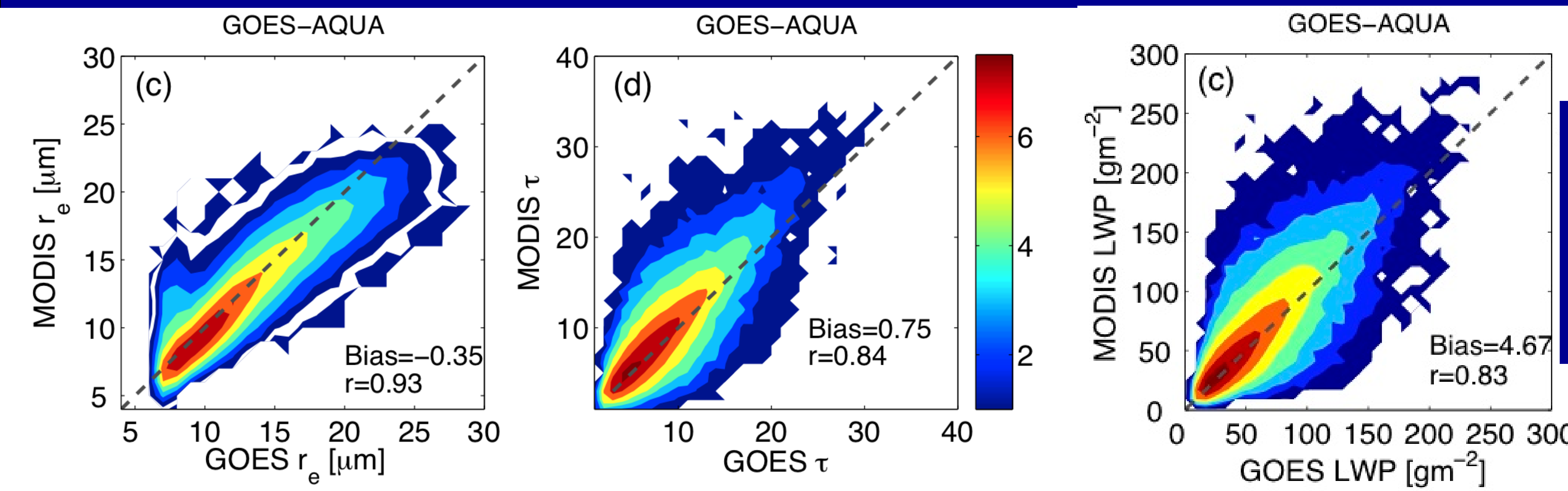
RMS = 1.9 (25%)

- Small differences in both droplet size and optical depth
- Optical depth differences at high end may be due to ozone differences

From *Painemal et al., JGR, submitted, 2012*

Consistency of GOES & **MODIS** Team Aqua µphysics Retrievals
Marine Stratus, SE Pacific, Oct – Nov 2008

R_e | Opt Depth | LWP



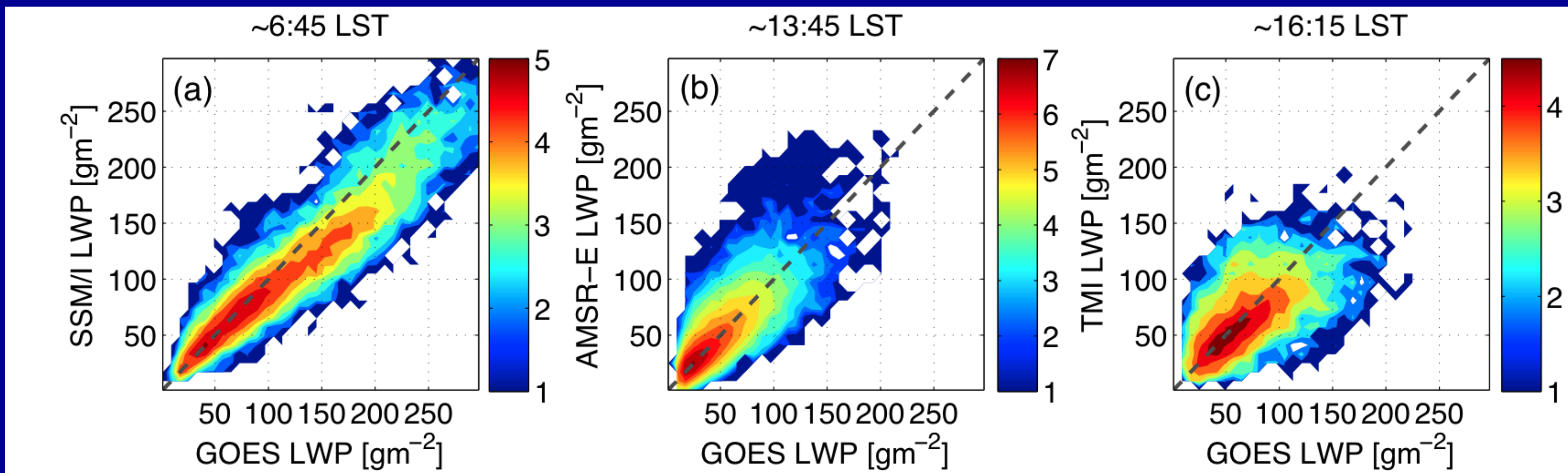
RMS = 1.3 µm (13%) | RMS = 1.9 (20%) | RMS = 20.5 gm^{-2} (37%)

- Small differences in both droplet size and optical depth
- Optical depth differences at high end may be due to ozone differences

From *Painemal et al., JGR, submitted, 2012*

Consistency of GOES LWP Retrievals With Solar Zenith Angle
Marine Stratus, SE Pacific, Oct – Nov 2008
Comparisons with Satellite µwave Retrievals

SSM/I | AMSR-E | TRMM TMI



	SSM/I	AMSR-E	TRMM TMI
R^2	0.87	0.79	0.56
Mean (gm^{-2})	7.9 (8%)	1.1 (2%)	3.9 (6%)
RMS	25.3	19.4	33.1

- Only a small dependence of bias on SZA from 0 – 70°
- GOES higher for LWP > 125 gm^{-2}, µwave uncertainty higher (drizzle)

From *Painemal et al., JGR, submitted, 2012*

Wrap-up for Final Ed4

- Mask much improved:
    - polar lines mostly disappeared
    - better consistency between Terra & Aqua
    - fewer false clouds due to mis-ID of aerosol
    - some tendency to overestimate clouds in SH polar region
        - *not every month, ~2% issue*
    - used homegrown calibrations, col 6 may cause some new problems

- ML algorithm now what it should be
    - picking up more ML in midlatitudes
    - better UL cloud taus