CERES CLOUDS STATUS

NASA : P. Minnis, D. F. Young

SAIC: S. Sun-Mack, Q. Trepte, Y. Chen, R. F. Arduini, R. Brown

AS&M: P. W. Heck

U. North Dakota: X. Dong

CERES STM, Princeton, NJ, September 17, 2002

TOPICS

- **Cloud mask changes**

- **Delivery of MODIS Edition 1a**

  ` **- Sensitivity to model errors**

  - Calibration sensitivities

  - Validation from climatology

  - Validation from ARM data

  - Consistency with VIRS

- **First Aqua MODIS data**

  - Initial results

  - 1.6-µm channel (Yuck!)

CHANGES TO CLOUDS SINCE Beta2

1. Altered logic for phase discrimination to improve thin ice cloud selection.

1.6-µm classifier not consistent for thin cloud class.
If LBTM cloud class is high, the outcome is more likely ice than before

2. Clear-sky snow & ice models updated & refined (higher angle resolution), improved snow/ice maps, updating now occurs over snow/ice regions

3. Polar mask algorithm retuned, accounts for calibration differences

4. Welch MODIS classifier implemented (VIRS & MODIS algos separate), used in polar regions to aid phase discrimination

5. Monthly clear-sky startup maps generated for MODIS, daily updating now

6. NoVIS (1.6, 3.7, 11.0 µm) algorithm turned on over snow

7. Detection of clouds in glint regions refined => fewer false clouds

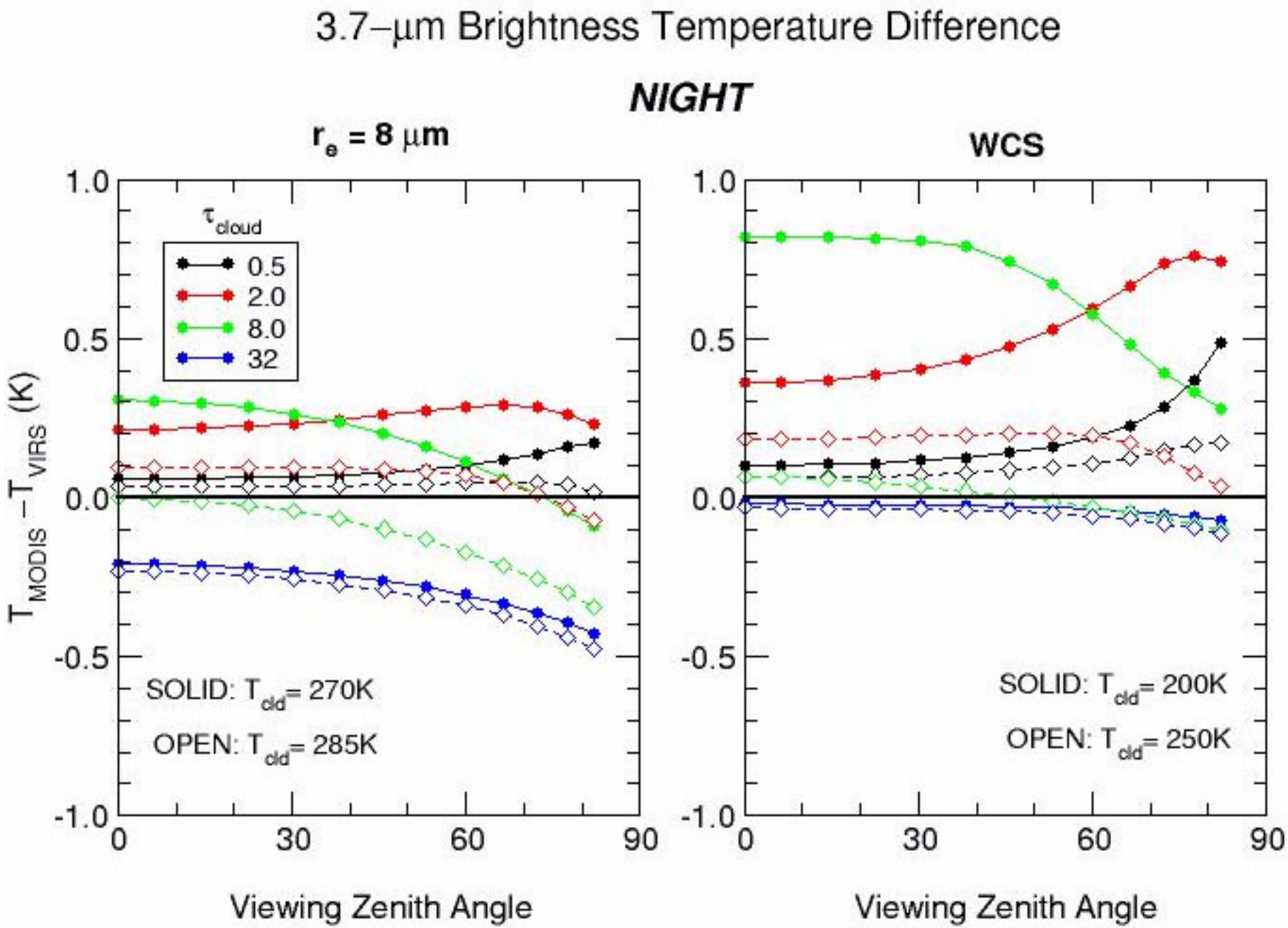
SENSITIVITY OF 3.7-μm TEMPERATURE TO FILTER

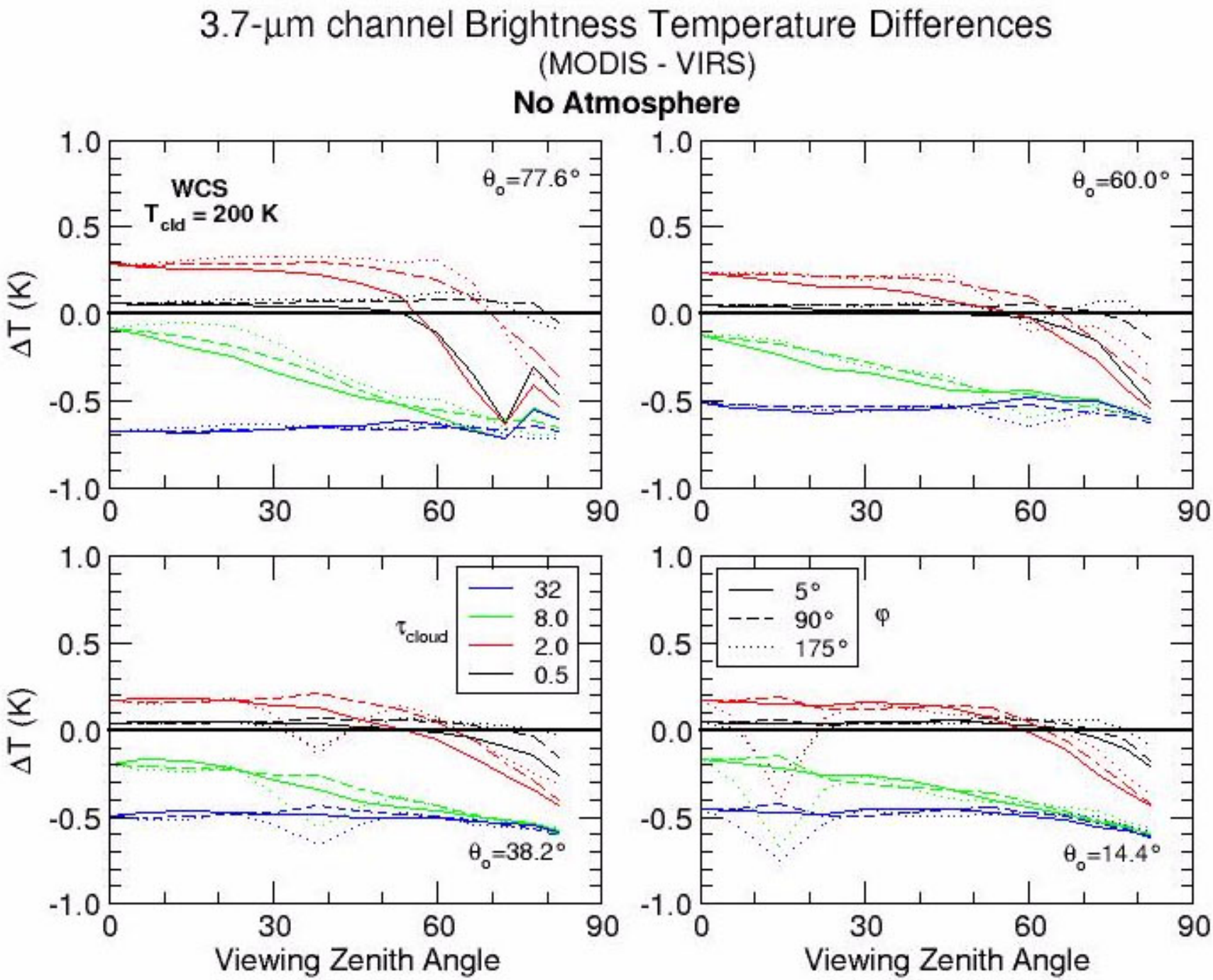
- **MODIS analyses using VIRS cloud emittance models, but filter functions slightly different**

  What is the impact on temperature?

- **Compute TOA temperature for surfaces & clouds at various temperatures using cloud optical properties computed for VIRS & MODIS filter functions**

- **MODIS reflectance models have been computed and used**


3.7–μm Brightness Temperature Difference
NIGHT
r_e = 8 μm
WCS
τ_{cloud}
0.5
2.0
8.0
32
SOLID: T_{cld}= 270K
OPEN: T_{cld}= 285K
SOLID: T_{cld}= 200K
OPEN: T_{cld}= 250K
$T_{MODIS} - T_{VIRS}$ (K)
1.0
0.5
0.0
-0.5
-1.0
0
30
60
90
Viewing Zenith Angle
Viewing Zenith Angle


3.7-µm channel Brightness Temperature Differences
(MODIS - VIRS)
No Atmosphere
WCS
T cld = 200 K
θo=77.6°
θo=60.0°
θo=38.2°
θo=14.4°
ΔT (K)
Viewing Zenith Angle
τcloud
32
8.0
2.0
0.5
φ
5°
90°
175°

IMPACT OF VIRS EMITTANCE MODELS

- Daytime re differences should be variable between -0.5 and 0.5 μm
  - Sometimes warmer / colder than expected
- Daytime De differences should be variable, but potentially large
  - VIRS > MODIS for $\tau < 2$
  - MODIS > VIRS for $\tau = 2 - 10$

- Will impact nighttime thin cloud heights, more study needed

- Insert MODIS models later?

CALIBRATION EFFECTS

- **VIRS & MODIS thermal calibrations differ by 0.1 to 0.5 K**

  => 3.7-µm difference yields MODIS re is 0.5 µm < VIRS

- **VIRS VIS reflectance greater at low values & smaller at high values**

  => MODIS optical depths should be greater for thick clouds

  => MODIS optical depths should be slightly smaller for thin clouds

SURFACE COMPARISON VALIDATION

- **ARM SGP**

  - **EVERYTHING APPEARS IN BOUNDS FOR PURE CLOUDS**

  - **LAND LOW-CLOUD HEIGHTS (use lapse rate approach)**

    See Dong talk tomorrow

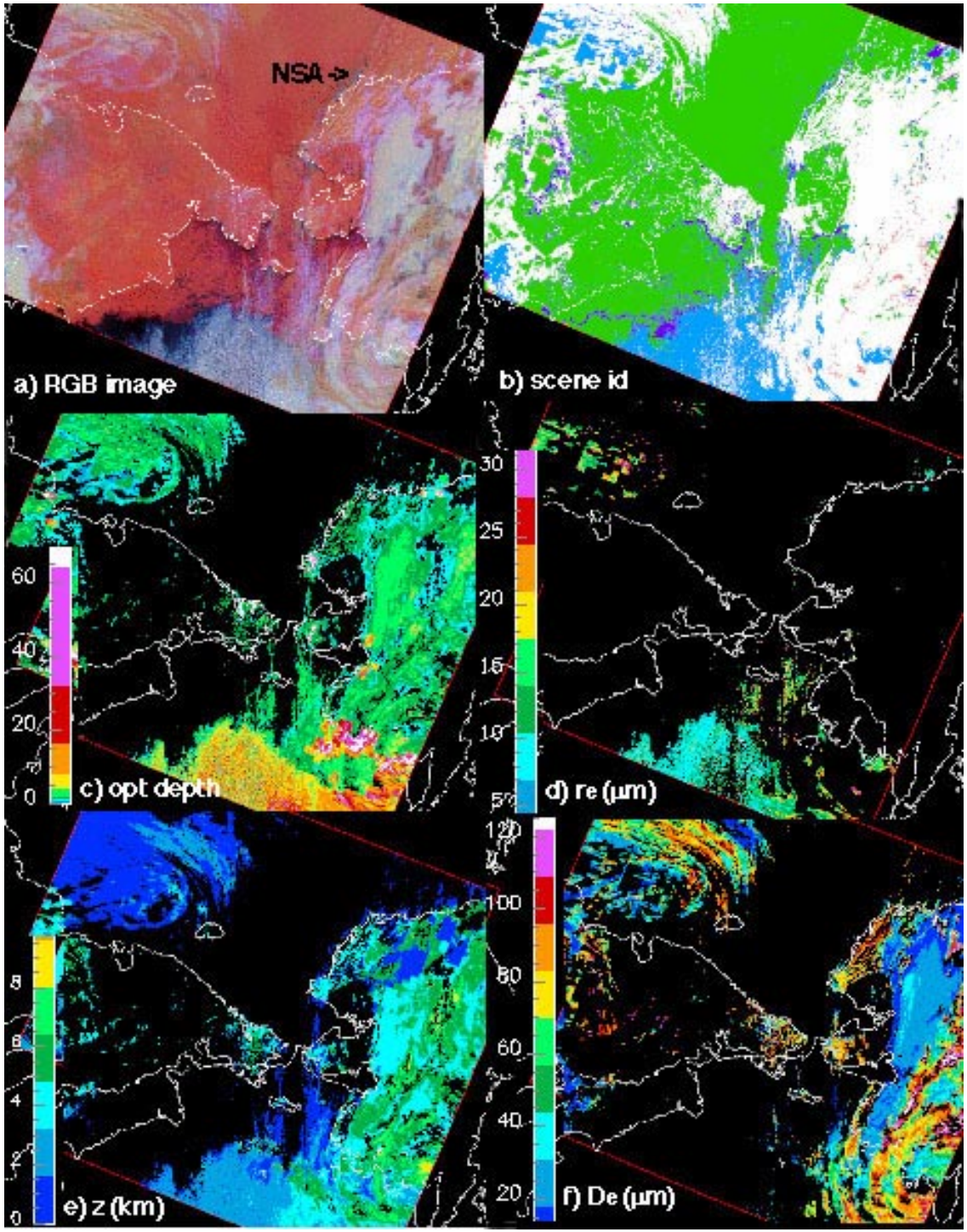
- **ARM NSA FIRST TRIES**

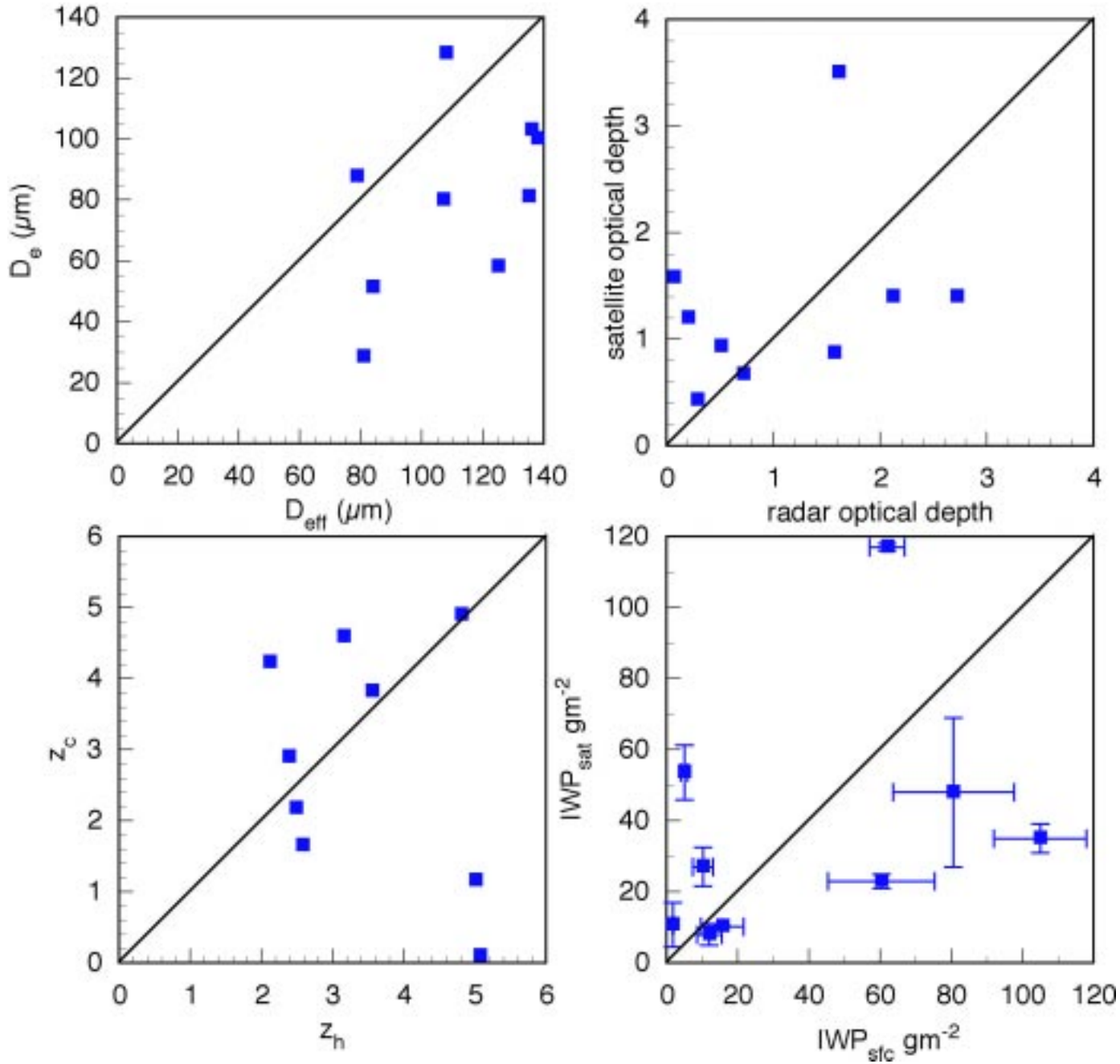
  - **ON AVERAGE OK**

    Instantaneous errors large for optically thin clouds

    Uttal talk?

Spangenberg, D. A., P. W. Heck, P. Minnis, Q. Z. Trepte, S. Sun-Mack, T. Uttal, S. Matrosov, and X. Dong, 2002: Arctic cloud properties derived from multispectral MODIS and AVHRR data. *Proc. 11th AMS Conf. Cloud Physics.*, Ogden, UT, June 3-7.


NSA ->
a) RGB image
b) scene id
c) opt depth
d) re (µm)
e) z (km)
f) De (µm)


D_e (μm)
D_{eff} (μm)
satellite optical depth
radar optical depth
z_c
z_h
IWP_{sat} gm^{-2}
IWP_{sfc} gm^{-2}

SURFACE EMISSIVITIES COMPUTED BUT NOT USED AT NIGHT

- MAY AFFECT HEIGHTS & CLOUD DETECTION
- IMPACT UNDER STUDY

RESULTS

CLOUD MASK CLEAR STATISTICS, DECEMBER 2000

Day: csz > 0.1

	Ocean	Land	Desert	Total
Clr Good	0.920	0.759	0.971	0.853
Clr Weak	0.009	0.010	0.015	0.009
Clr Smoke	0.001	0.000	0.000	0.001
Clr Fire	0.000	0.000	0.000	0.000
Clr Snow	0.017	0.228	0.009	0.108
Clr Glint	0.052	0.001	0.000	0.028
Clr Shadow	0.000	0.001	0.005	0.001
Clr Aerosol	0.002	0.000	0.000	0.001
Total	1.000	1.000	1.000	1.000

7% increase!

Night: csz < 0.1

	Ocean	Land	Desert	Total
Clr Good	0.704	0.661	0.717	0.687
Clr Weak	0.076	0.032	0.211	0.062
Clr Snow	0.220	0.307	0.072	0.251
Total	1.000	1.000	1.000	1.000

CLOUD MASK CLOUD STATISTICS, DECEMBER 2000

Day: csz > 0.1

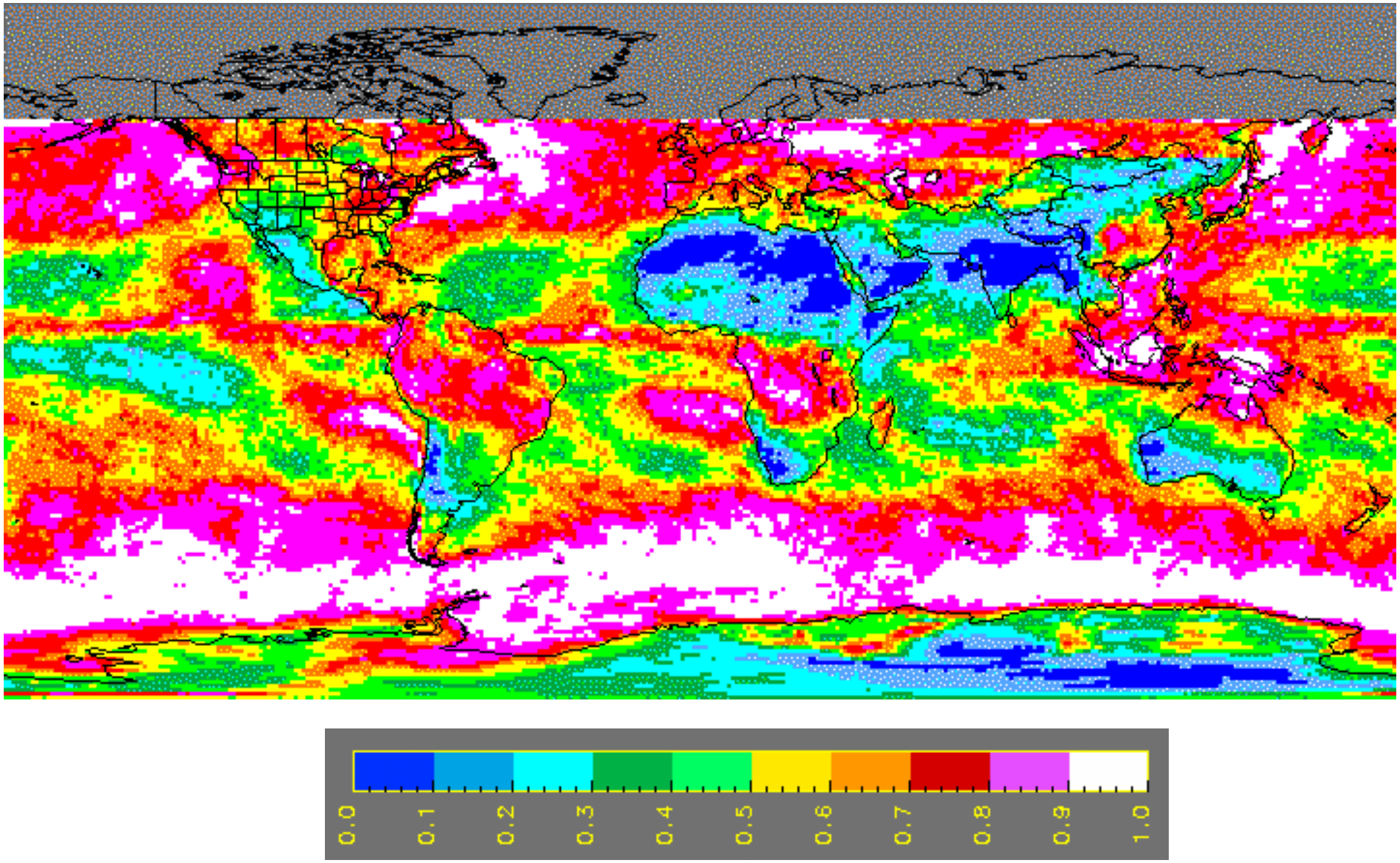
	Ocean	Land	Desert	Total
Cld Good	0.940	0.855	0.662	0.912
Cld Weak	0.038	0.042	0.088	0.047
Cld Glint	0.009	0.001	0.000	0.007
Cld N/R	0.030	0.068	0.250	0.042
Total	1.000	1.000	1.000	1.000

Night: csz < 0.1

	Ocean	Land	Desert	Total
Cld Good	0.909	0.906	0.909	0.908
Cld Weak	0.084	0.084	0.038	0.084
Cld N/R	0.007	0.009	0.053	0.014
Total	1.000	1.000	1.000	1.000

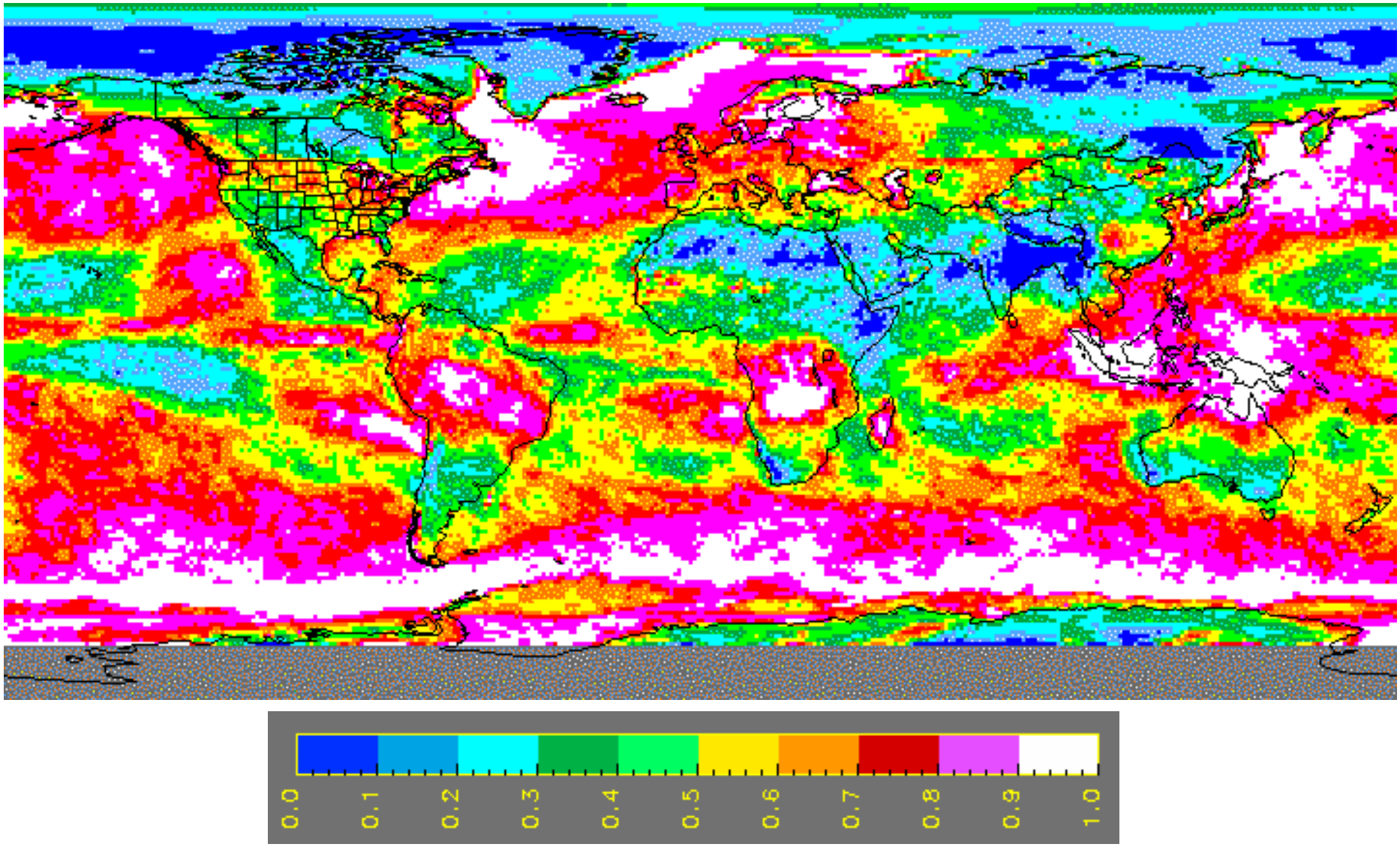
MEAN CLOUD COVER, MODIS, DEC 2000

DAYTIME



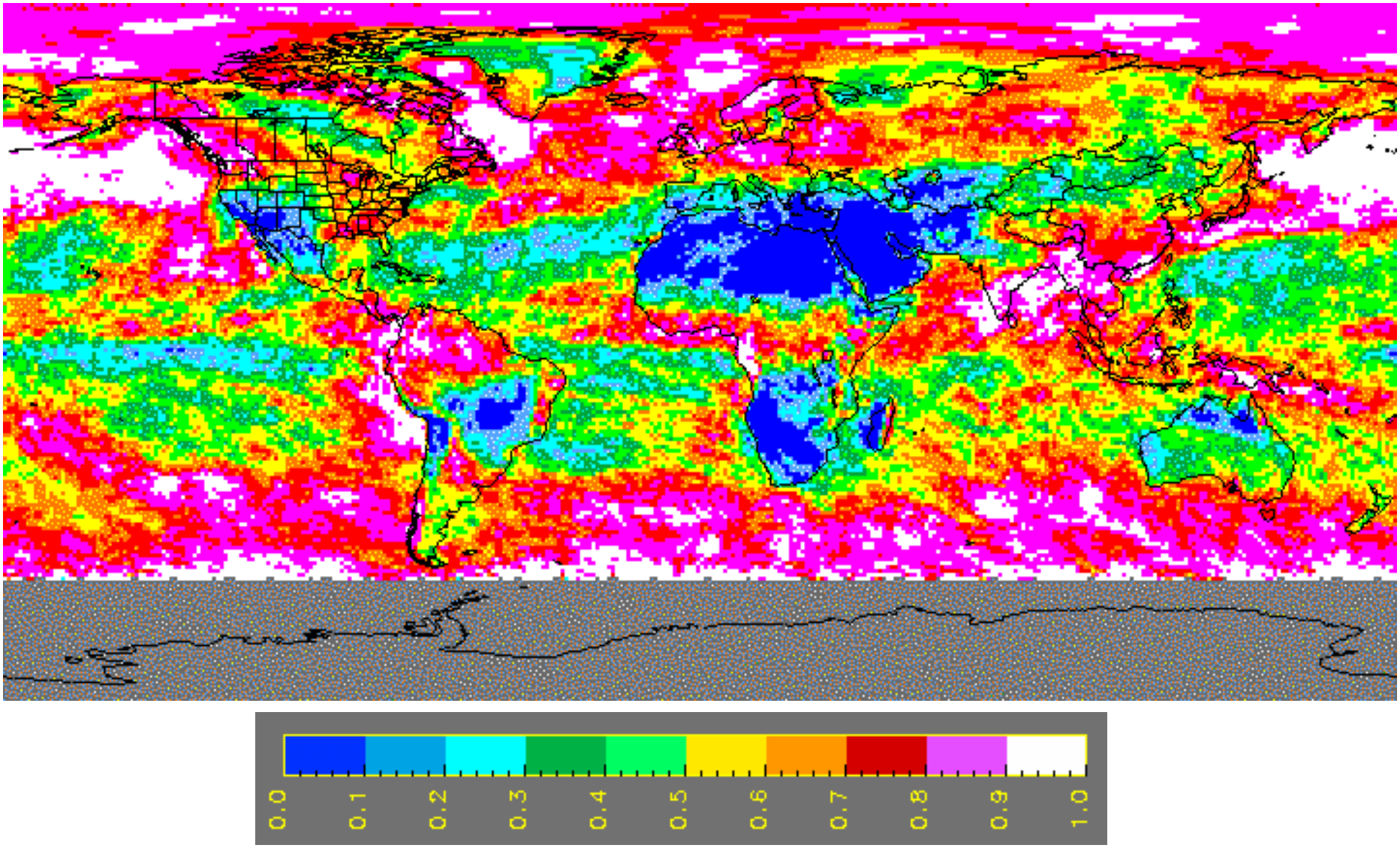
MEAN CLOUD COVER, MODIS, DEC 2000

NIGHT



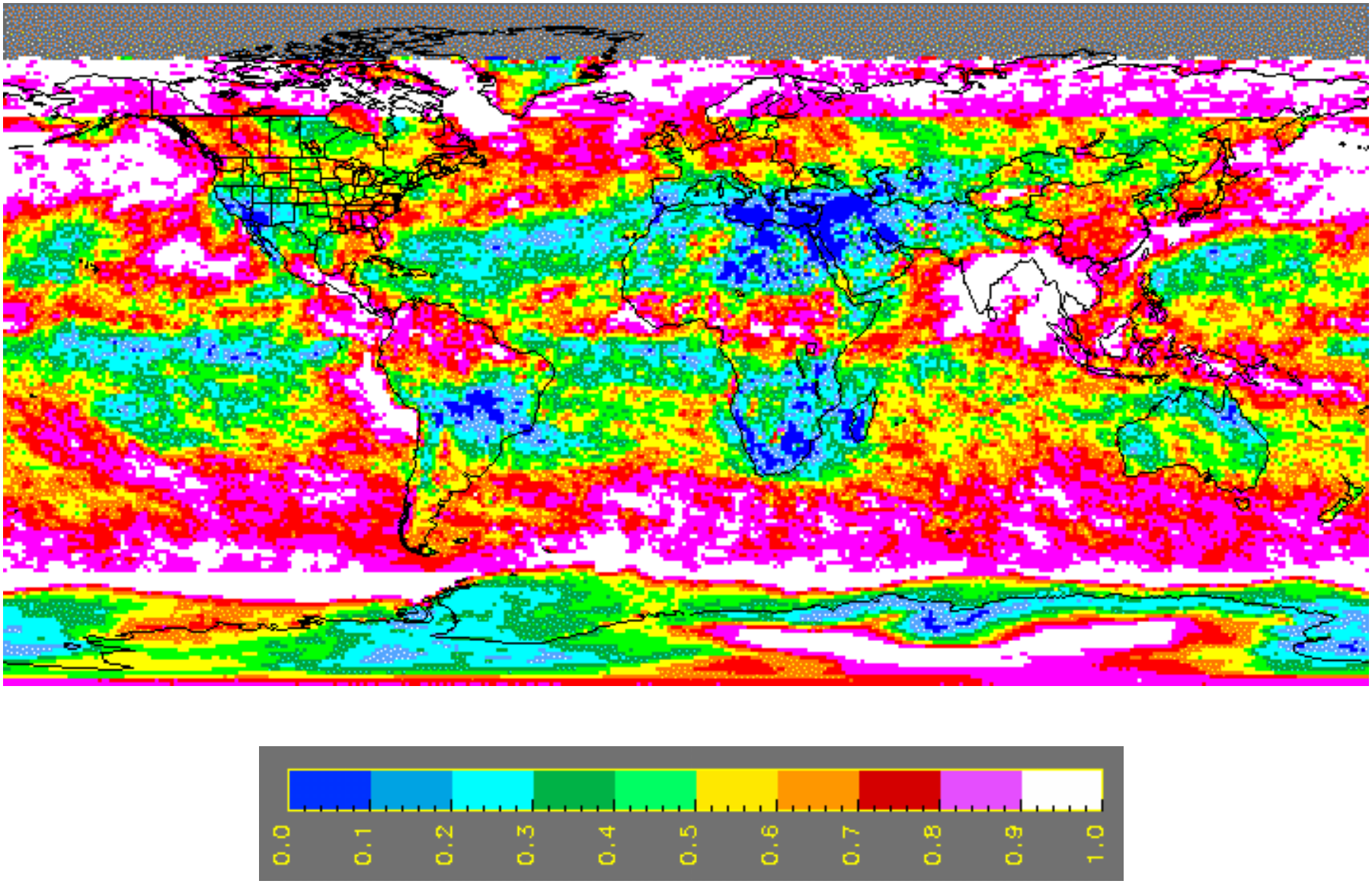
MEAN CLOUD COVER, MODIS, June 2001

Day



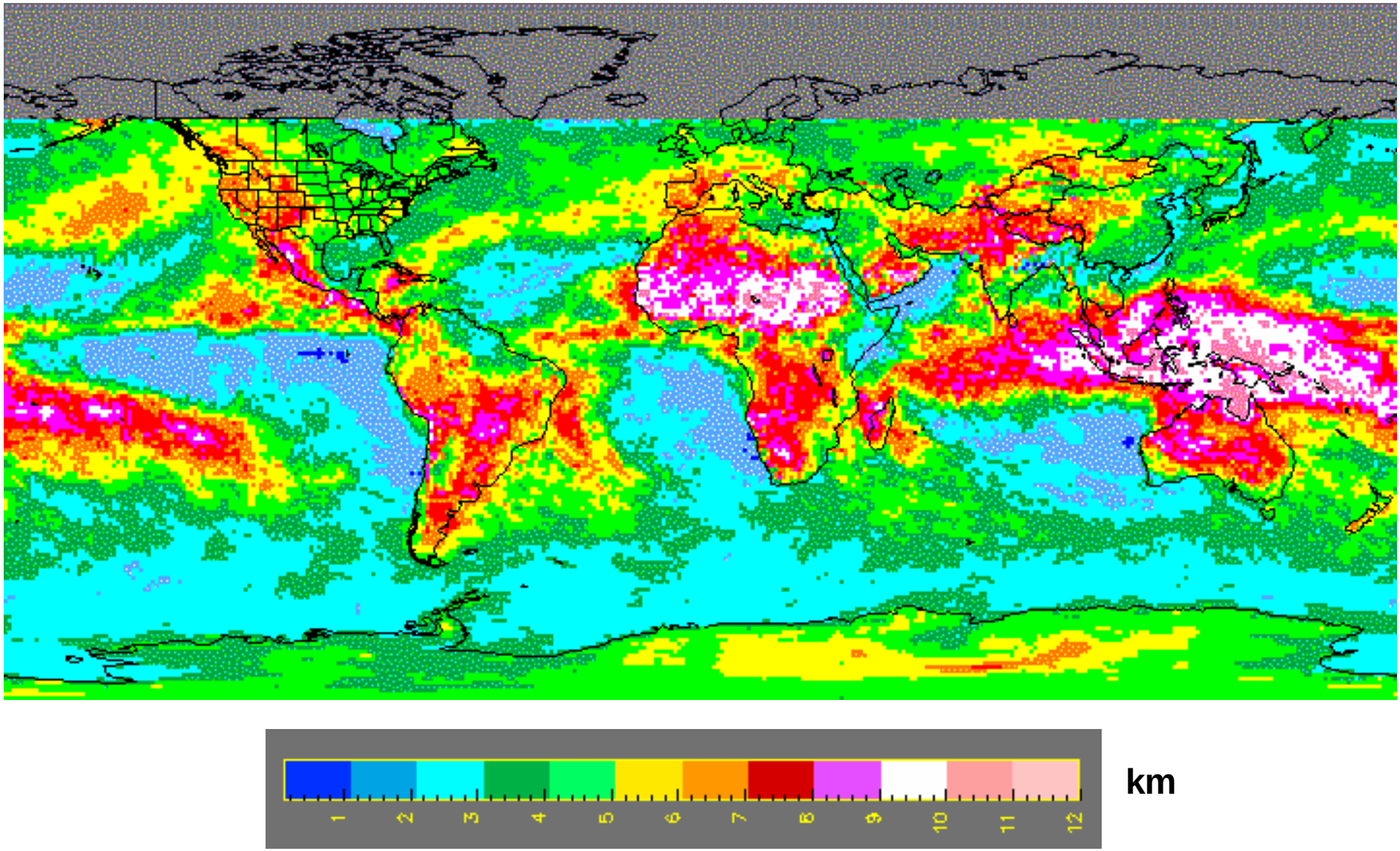
MEAN CLOUD COVER, MODIS, June 2001

night



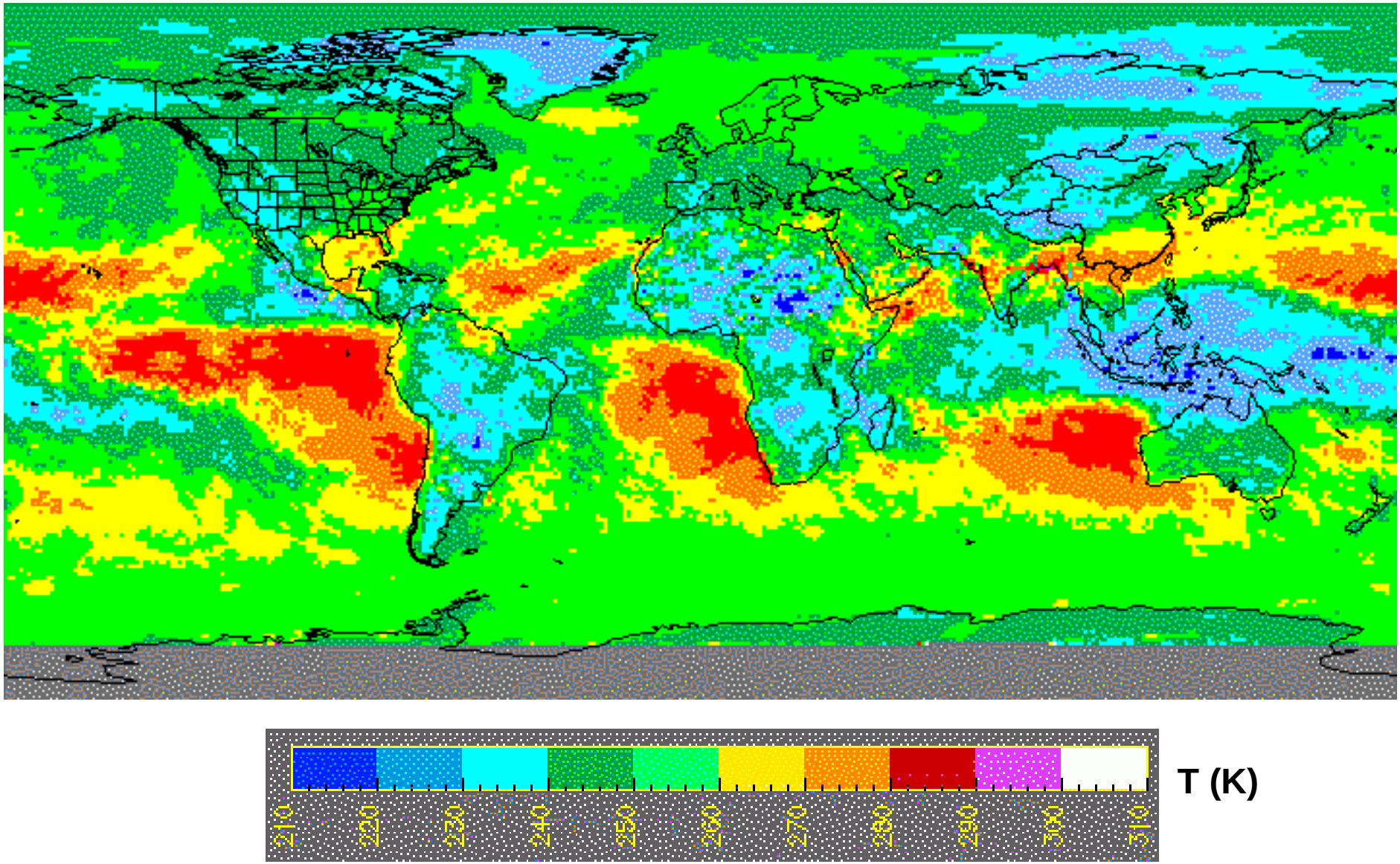
MEAN EFFECTIVE CLOUD HEIGHT, MODIS, DEC 2000

DAYTIME



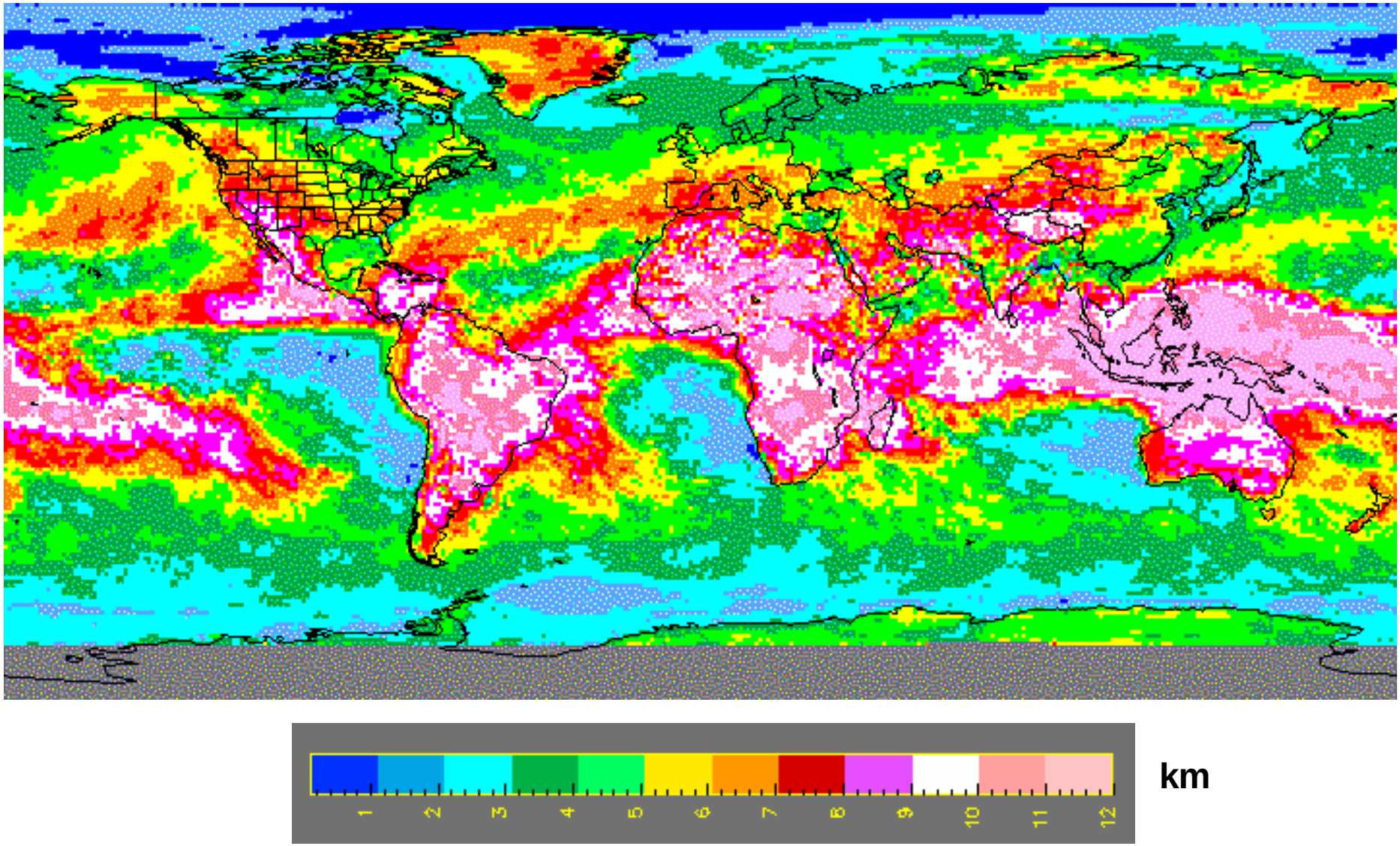
EFFECTIVE CLOUD TEMPERATURE, MODIS, DEC 2000

DAY

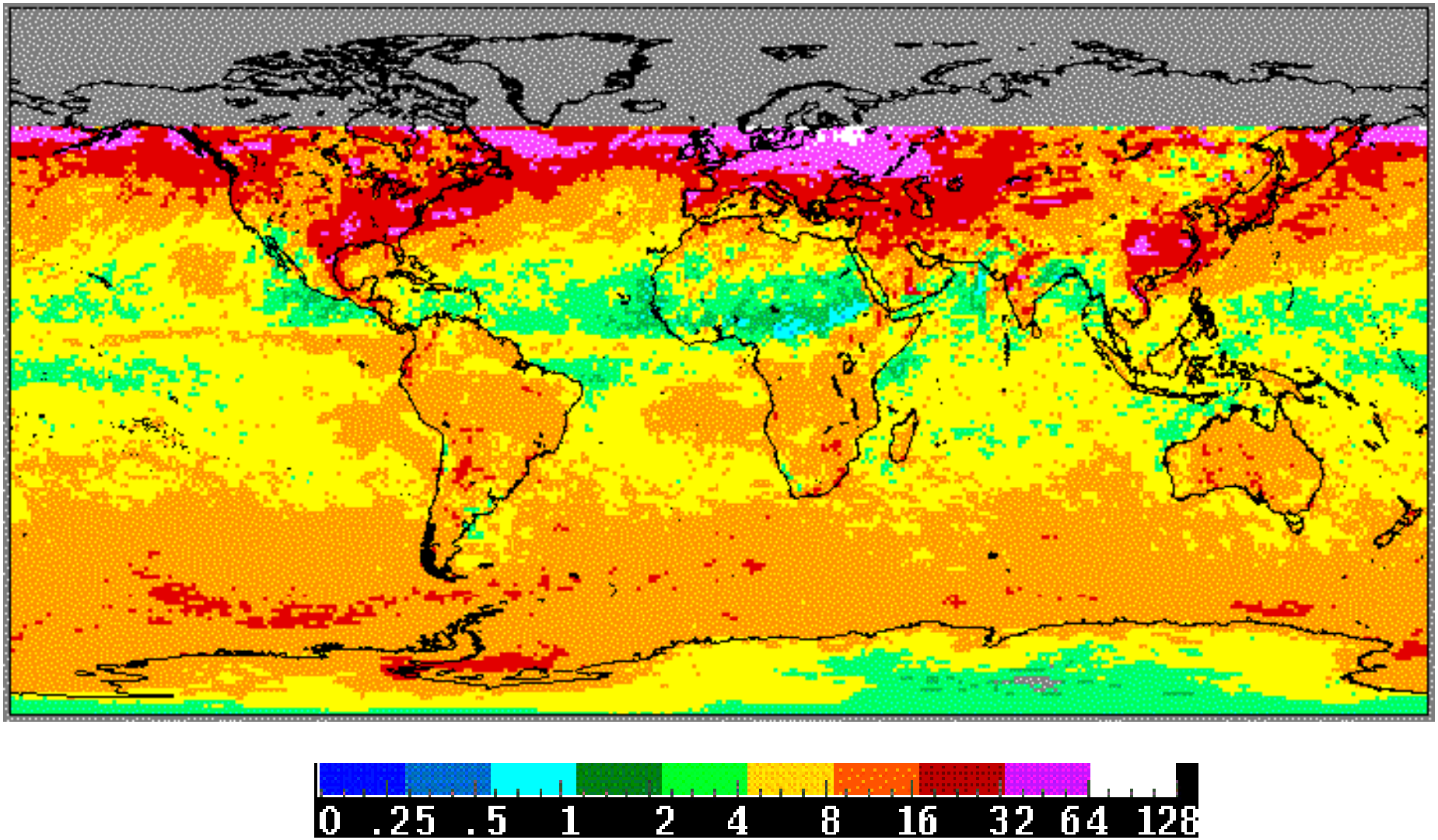


MEAN EFFECTIVE CLOUD HEIGHT, MODIS, DEC 2000

NIGHT

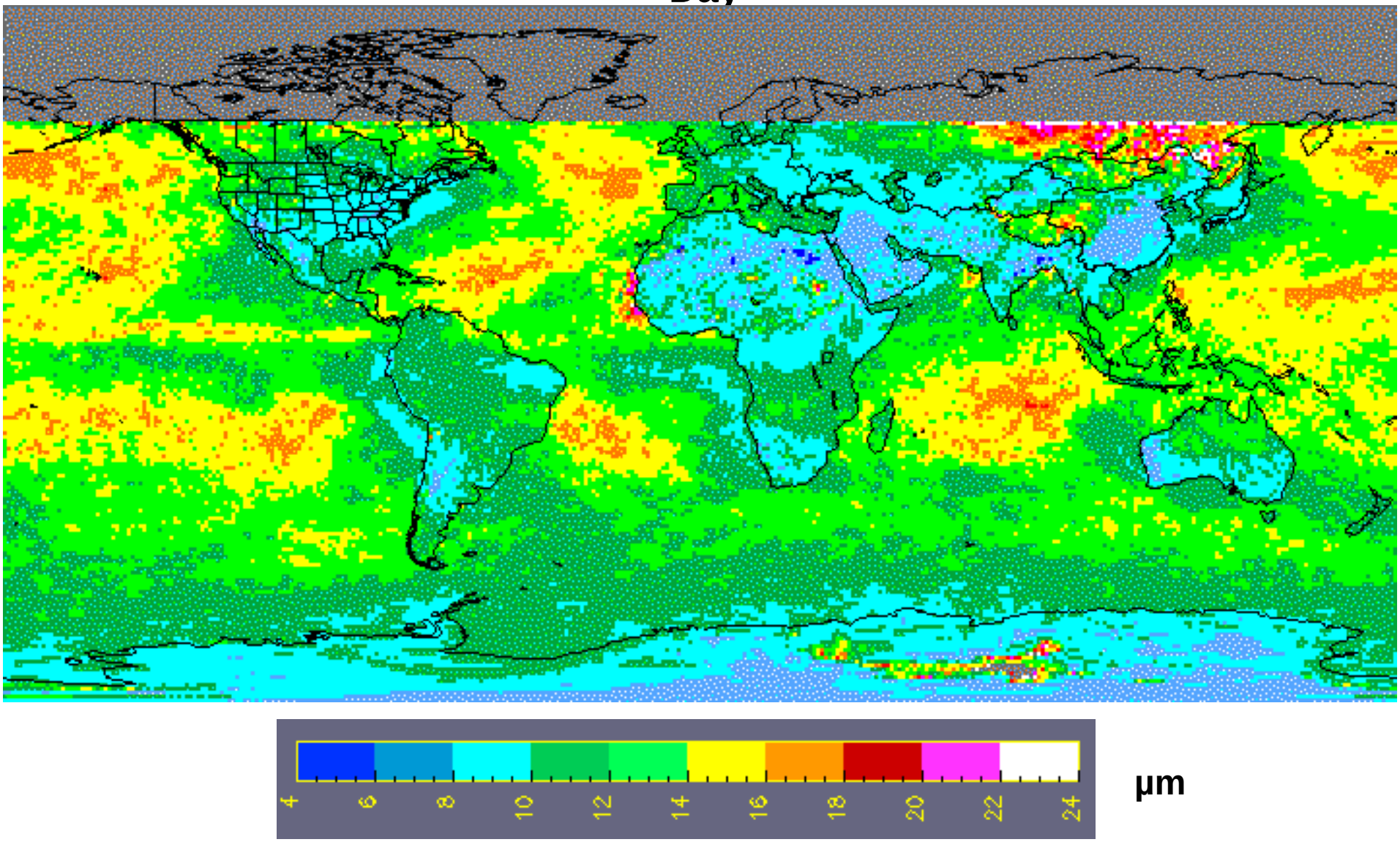


MEAN WATER CLOUD OPTICAL DEPTH, MODIS, DEC 2000, DAY



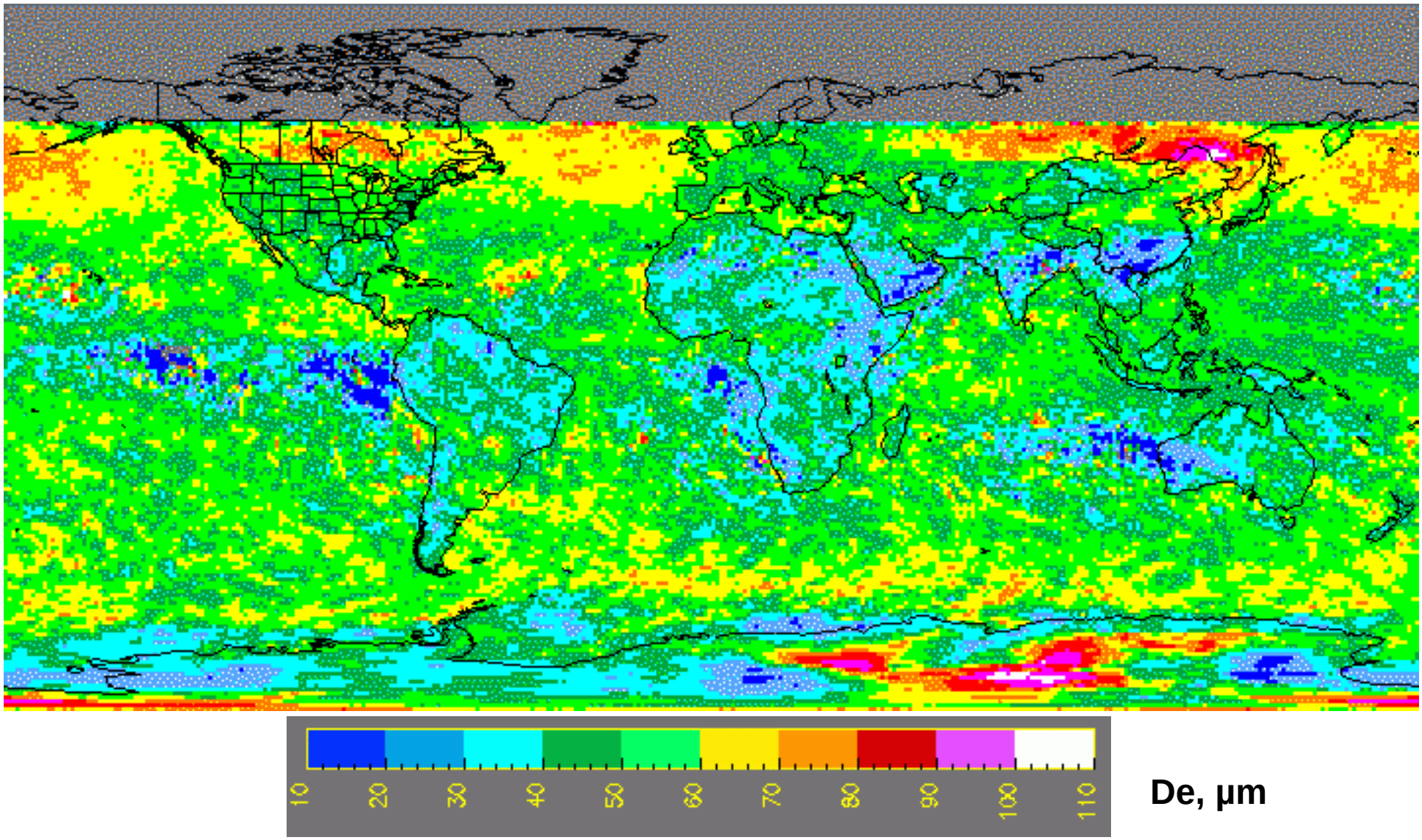
MEAN EFFECTIVE DROPLET RADIUS, MODIS, DEC 2000

Day



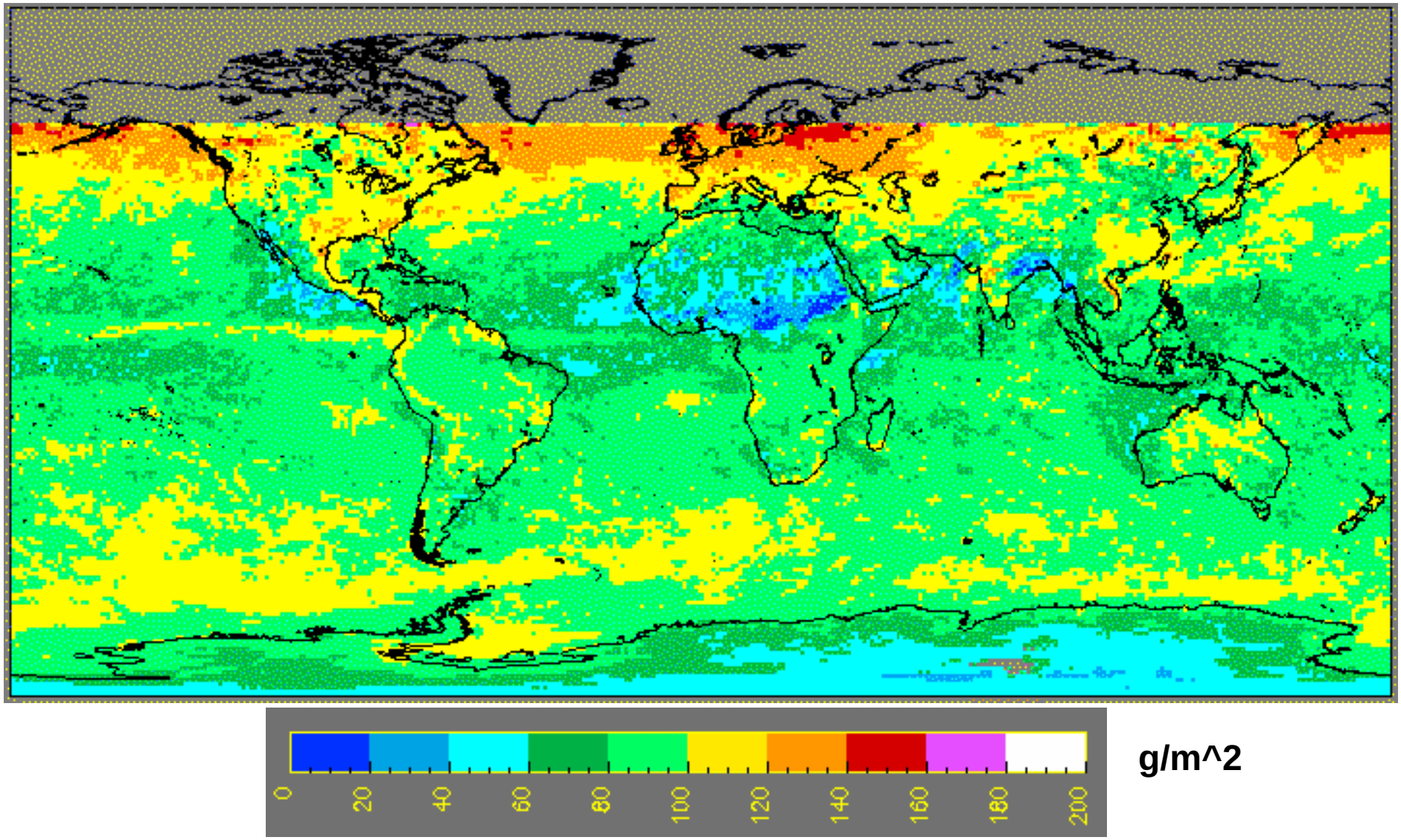
MEAN EFFECTIVE ICE CRYSTAL DIAMETER , MODIS, DEC 2000

DAYTIME

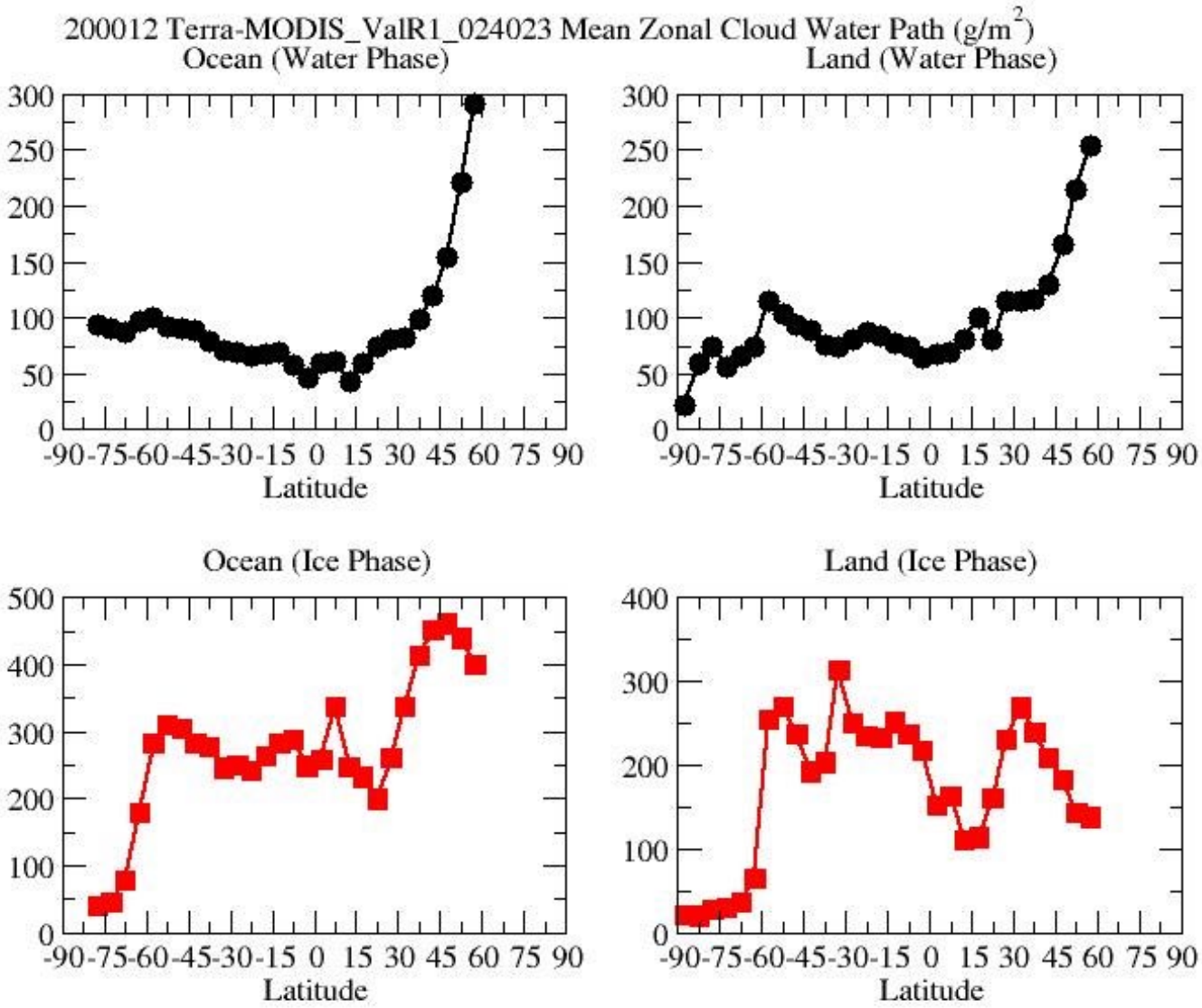


MEAN CLOUD LIQUID WATER PATH, MODIS DEC 2000

Daytime



MEAN WATER PATH, MODIS, DEC 2000, DAY



SOME REFERENCES

Minnis, P., L. Nguyen, D. R. Doelling, D. F. Young, W. F. Miller, and D. P. Kratz, 2002: Rapid calibration of operational and research meteorological satellite imagers, Part I: Evaluation of research satellite visible channels as references. In press, *J. Atmos. Oceanic Technol*.

Minnis, P., L. Nguyen, D. R. Doelling, D. F. Young, W. F. Miller, and D. P. Kratz, 2002: Rapid calibration of operational and research meteorological satellite imagers, Part II: Comparison of infrared channels. In press, *J. Atmos. Oceanic Technol*.

Minnis, P., D. F .Young, B. A. Wielicki, et al., 2002: Seasonal and diurnal variations of cloud properties derived for CERES from VIRS and MODIS data. *Proc. 11th AMS Conf. Atmos. Rad.*, Ogden, UT, June 3-7.

Heck, P. W., P. Minnis, D. F. Young, and S. Sun-Mack, 2002: Angular variations of cloud properties from VIRS and MODIS data. *Proc. 11th AMS Conf. Atmos. Rad.*, Ogden, UT, June 3-7.

Chen, Y., S. Sun-Mack, Q. Z. Trepte, P. Minnis, and D. F. Young, 2002: Solar zenith angle variation of clear-sky narrowband albedos derived from VIRS and MODIS. *Proc. 11th AMS Conf. Atmos. Rad.*, Ogden, UT, June 3-7.

Chen, Y., S. Sun-Mack, P. Minnis, D. F. Young, and W. L. Smith, Jr., 2001: Surface emissivity derived for infrared remote sensing from satellites. *Proc. AMS 11th Conf. Satellite Meteorology and Oceanography*, Madison, WI, Oct. 15-18, 512-515.

Trepte, Q., R. F. Arduini, Y. Chen, et al., 2001: Development of a daytime polar cloud mask using theoretical models of near- infrared bidirectional reflectance for ARM and CERES. *Proc. AMS 6th Conf. on Polar Meteorology and Oceanography*, San Diego, CA, May 14-18, 242-245.

APPARENT PROBLEMS

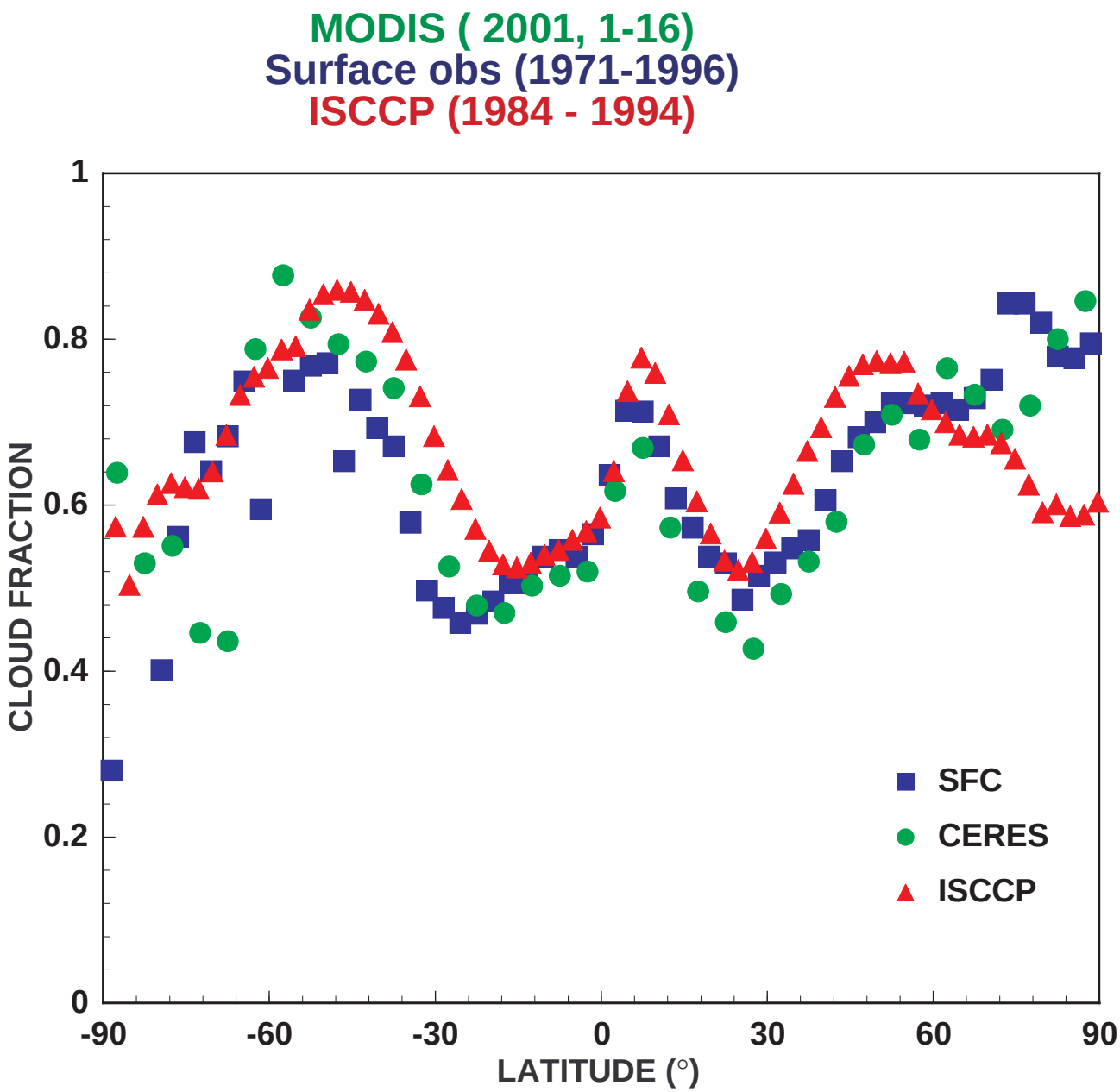
- **NIGHTTIME POLAR CLOUD MASK**
  - too few clouds, need additional study
  - impact minimal on CERES because night in relatively dry atmosphere?

- **POLAR DROPLET SIZES SEEM SMALL**
  - Using SINT producing apparent discontinuity over snow/ice
  - additional study could help resolve the problem
  - current result better than alternative

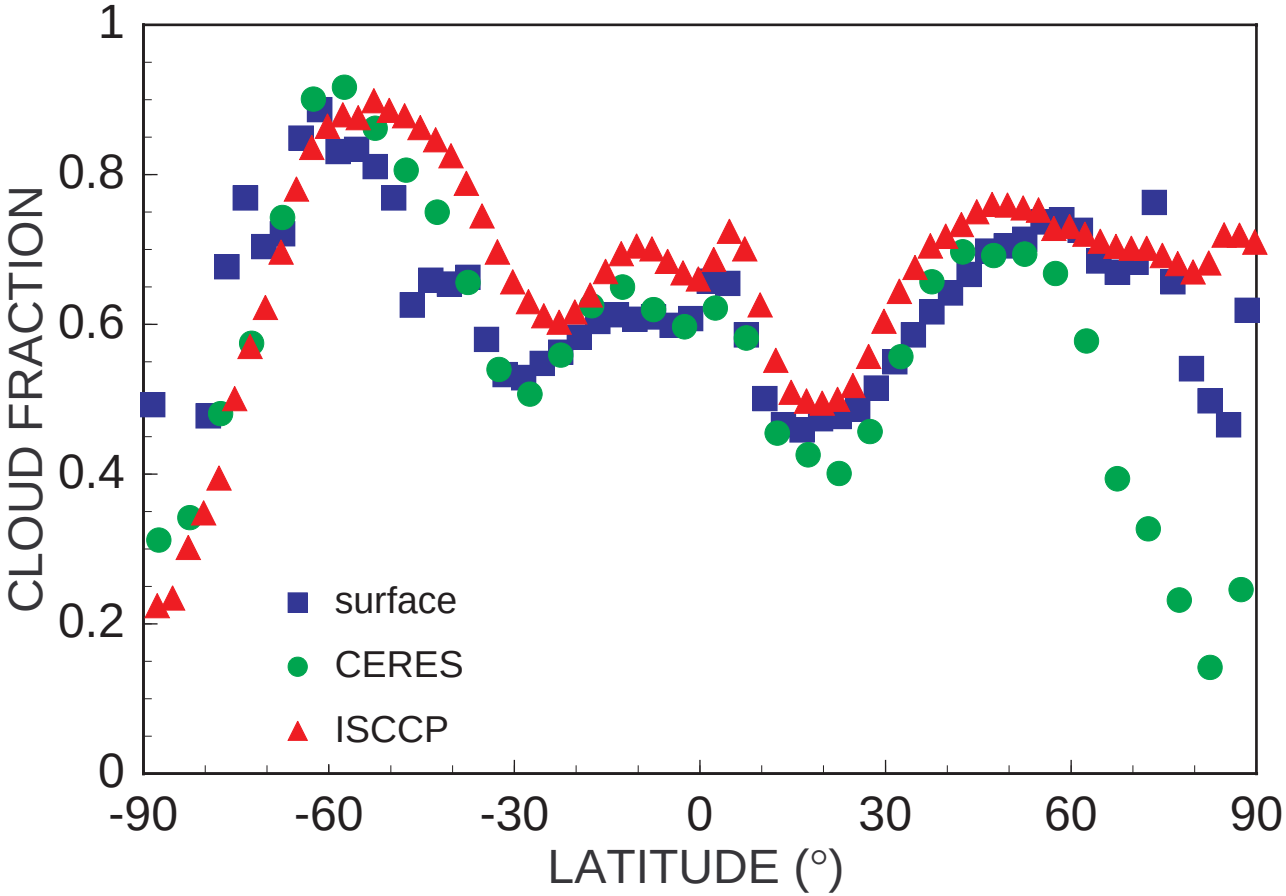
- **NIGHTTIME SHIFT IN CLOUD HEIGHT**
  - Possibly due to lack of sfc emissivity at all wavelengths
  - Low cloud effect not apparent in overlap conditions

COMPARISONS WITH CLIMATOLOGY

Mean Cloud Fraction, June



MEAN CLOUD FRACTION, DEC



	SURFACE	CERES	ISCCP
ALL	0.632	0.563	0.669
60N - 60S	0.606	0.625	0.696
	71-96	00	84-94

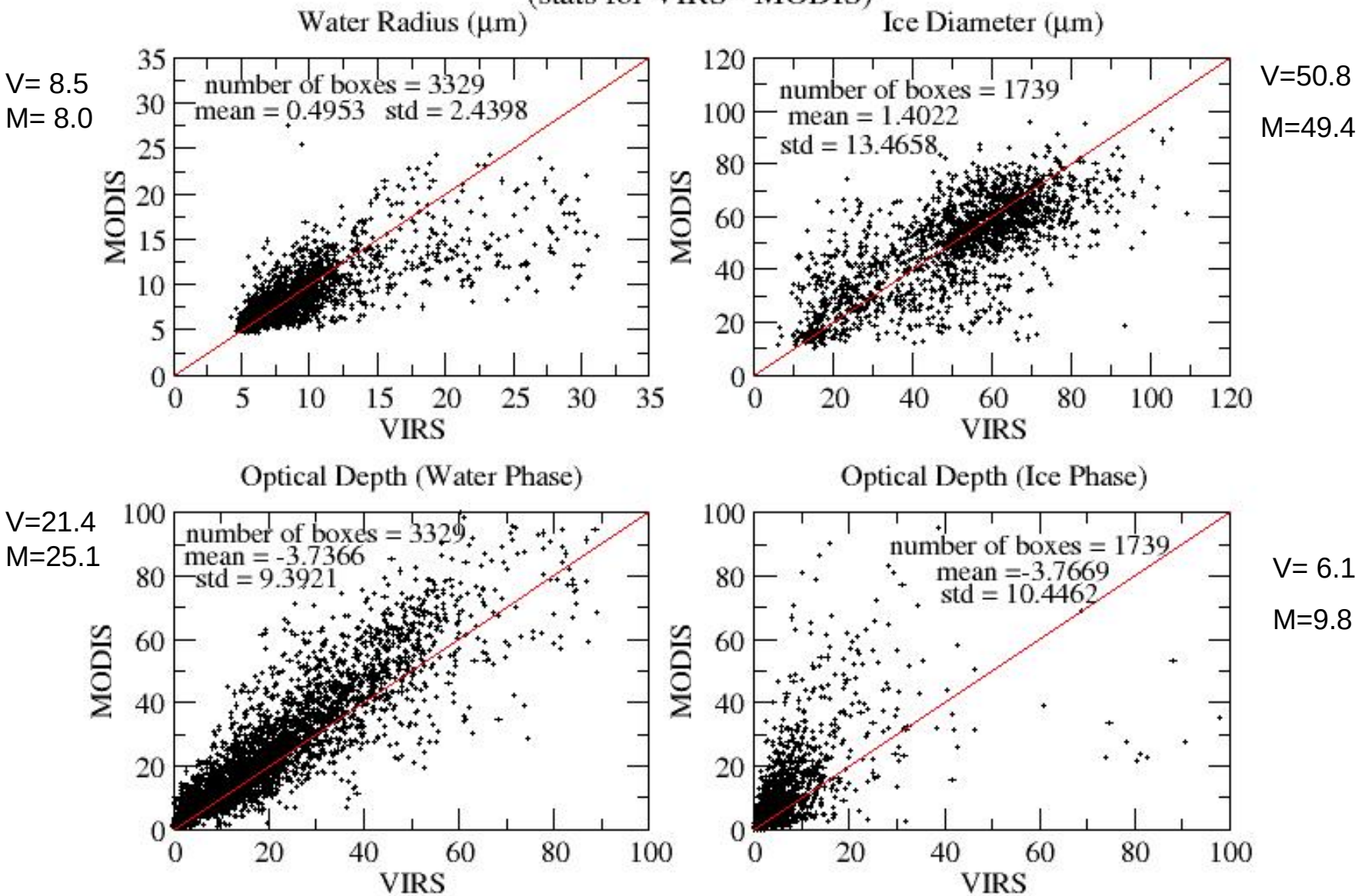
CONSISTENCY WITH VIRS

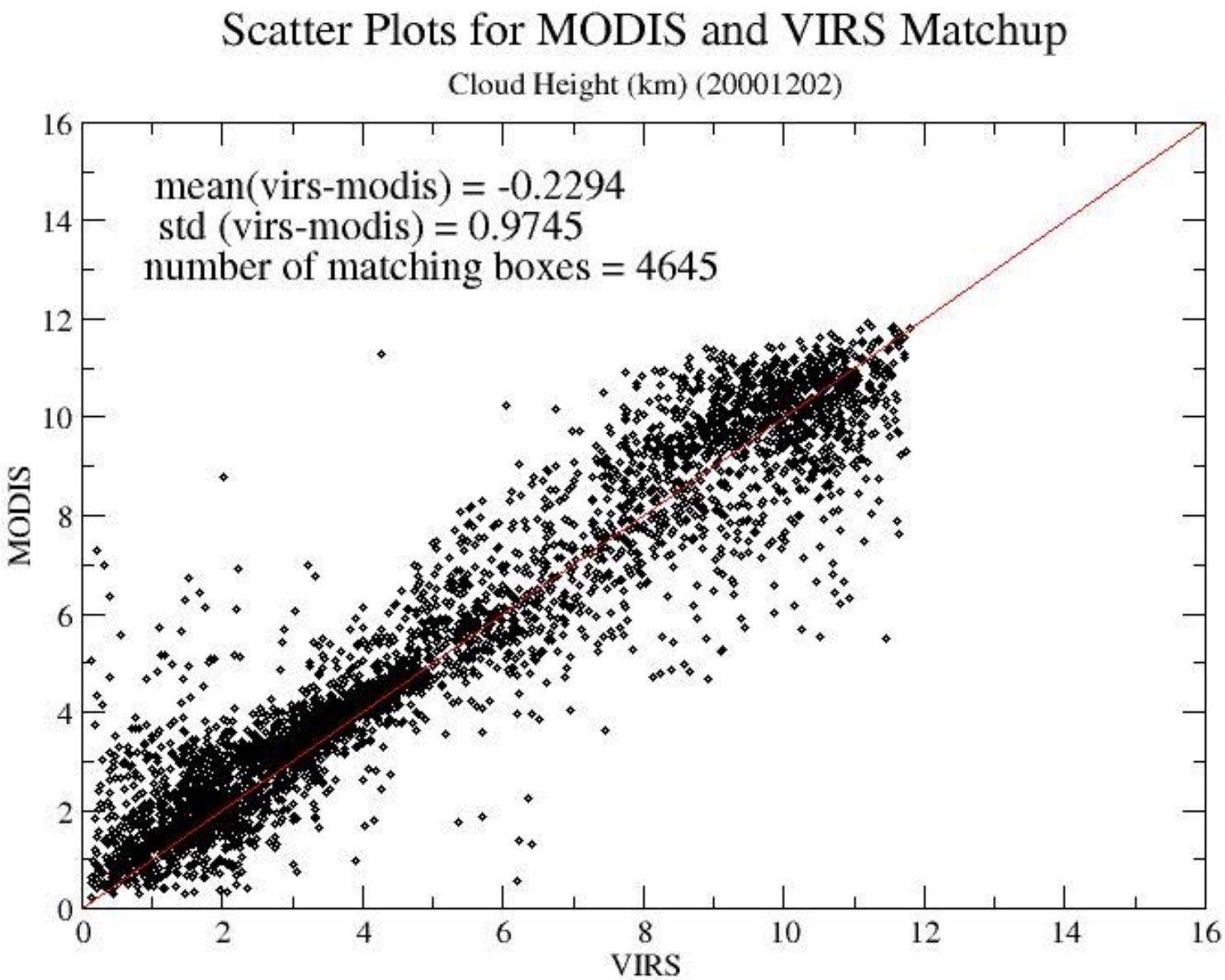
Scatter Plots for MODIS and VIRS Matchup

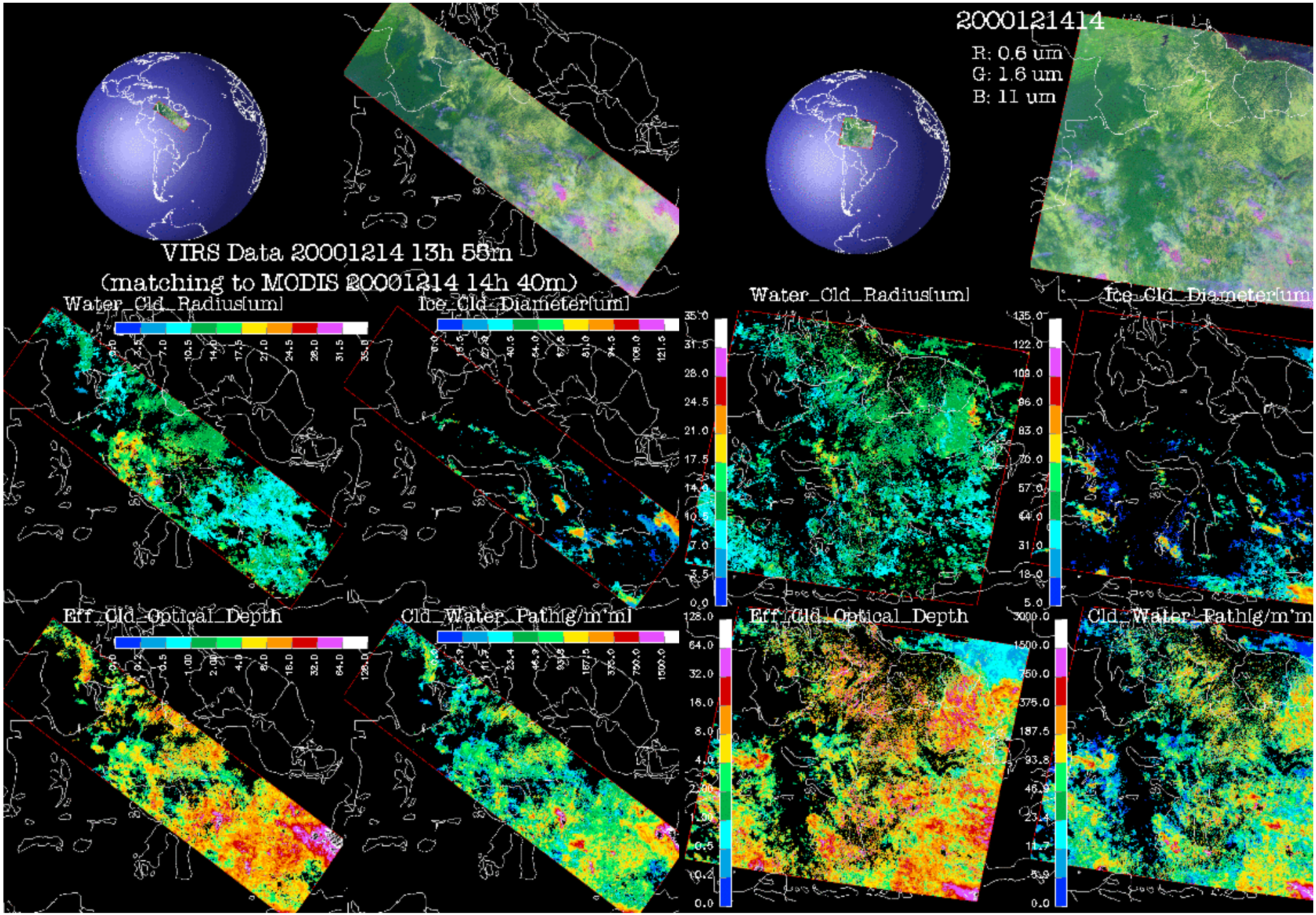
MODIS (200012021725) and VIRS (200012021654)

(stats for VIRS - MODIS)

Δt = 31 min




Scatter Plots for MODIS and VIRS Matchup
Cloud Height (km) (20001202)
mean(virs-modis) = -0.2294
std (virs-modis) = 0.9745
number of matching boxes = 4645
MODIS
VIRS
0
2
4
6
8
10
12
14
16

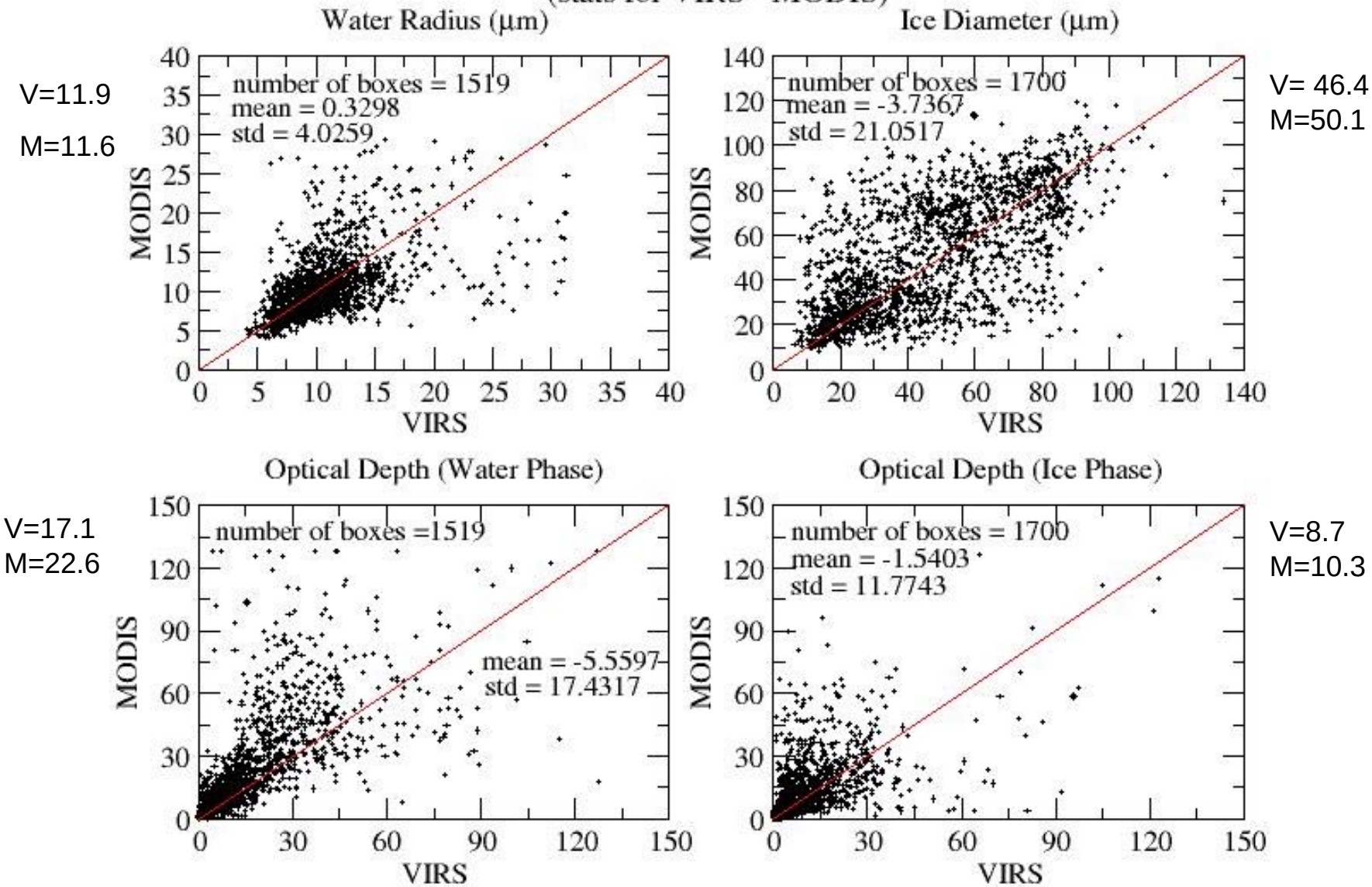

2000121414
R: 0.6 um
G: 1.6 um
B: 11 um
VIRS Data 20001214 13h 55m
(matching to MODIS 20001214 14h 40m)
Water_Cld_Radius[um]
Ice_Cld_Diameter[um]
Eff_Cld_Optical_Depth
Cld_Water_Path[g/m'm]
Water_Cld_Radius[um]
Ice_Cld_Diameter[um]
Eff_Cld_Optical_Depth
Cld_Water_Path[g/m'm]

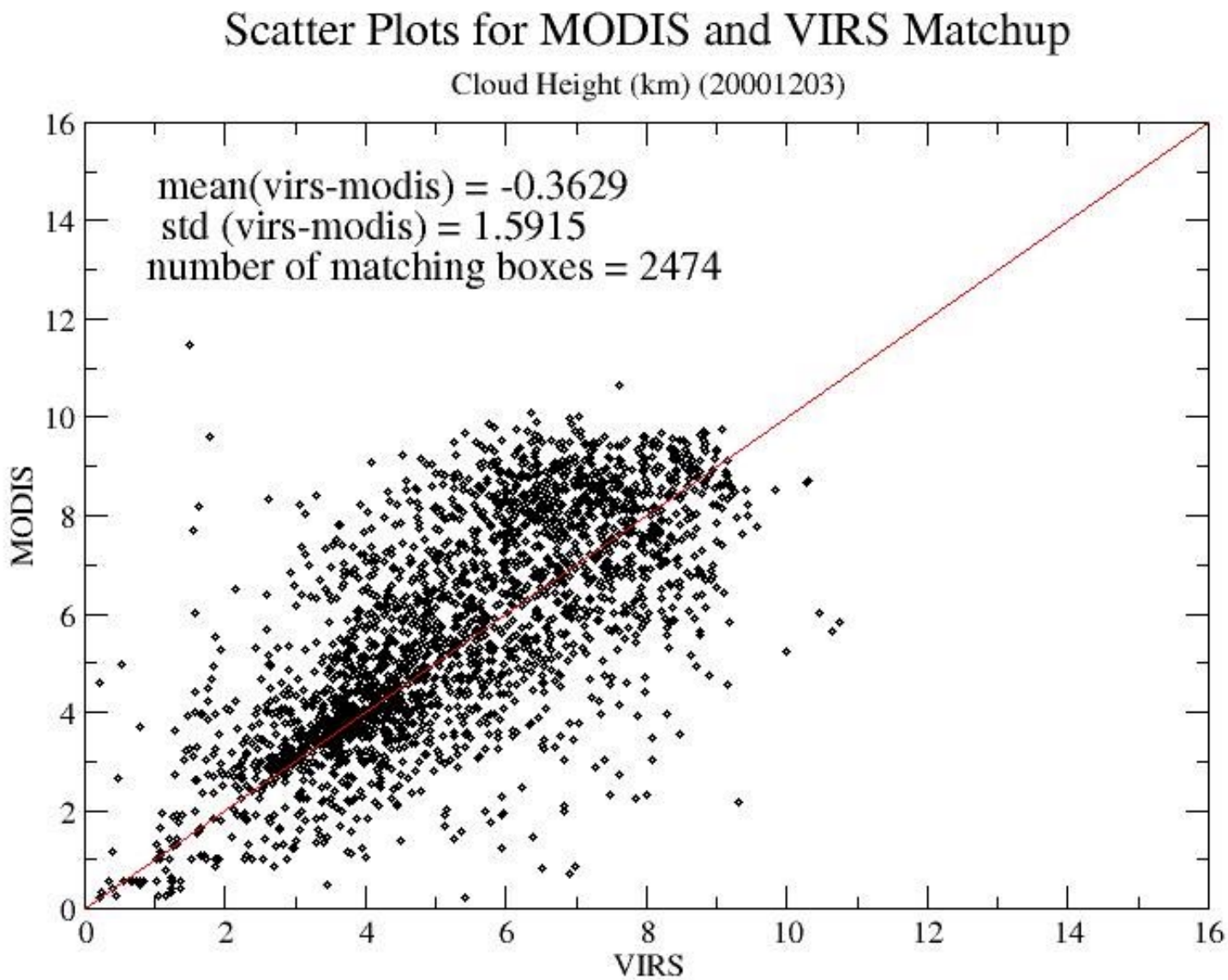
Scatter Plots for MODIS and VIRS Matchup

MODIS (200012031805) and VIRS (200012031718)

(stats for VIRS - MODIS)

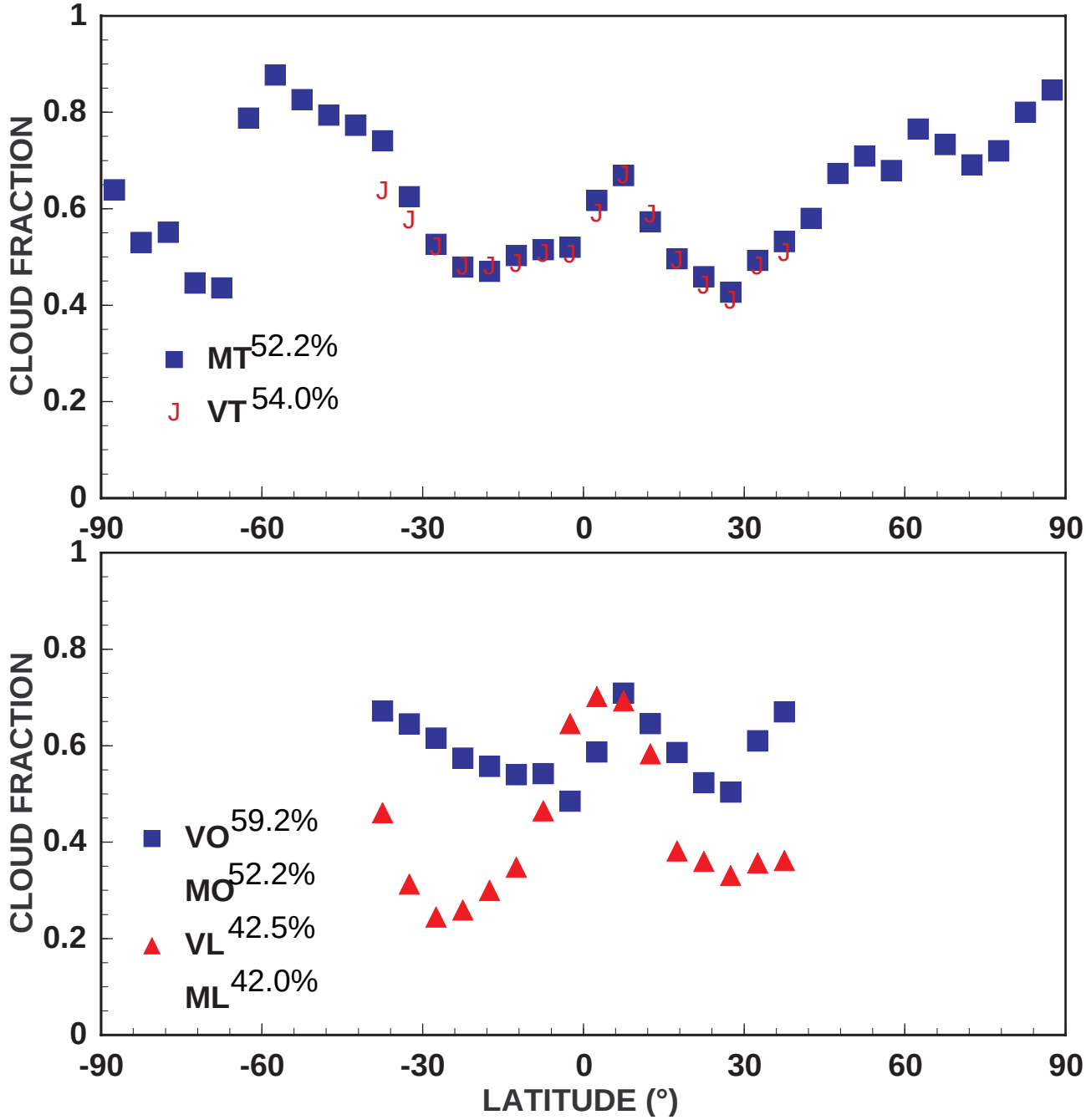
Δt = 47 min




Scatter Plots for MODIS and VIRS Matchup
Cloud Height (km) (20001203)
mean(virs-modis) = -0.3629
std (virs-modis) = 1.5915
number of matching boxes = 2474
MODIS
VIRS
0
2
4
6
8
10
12
14
16

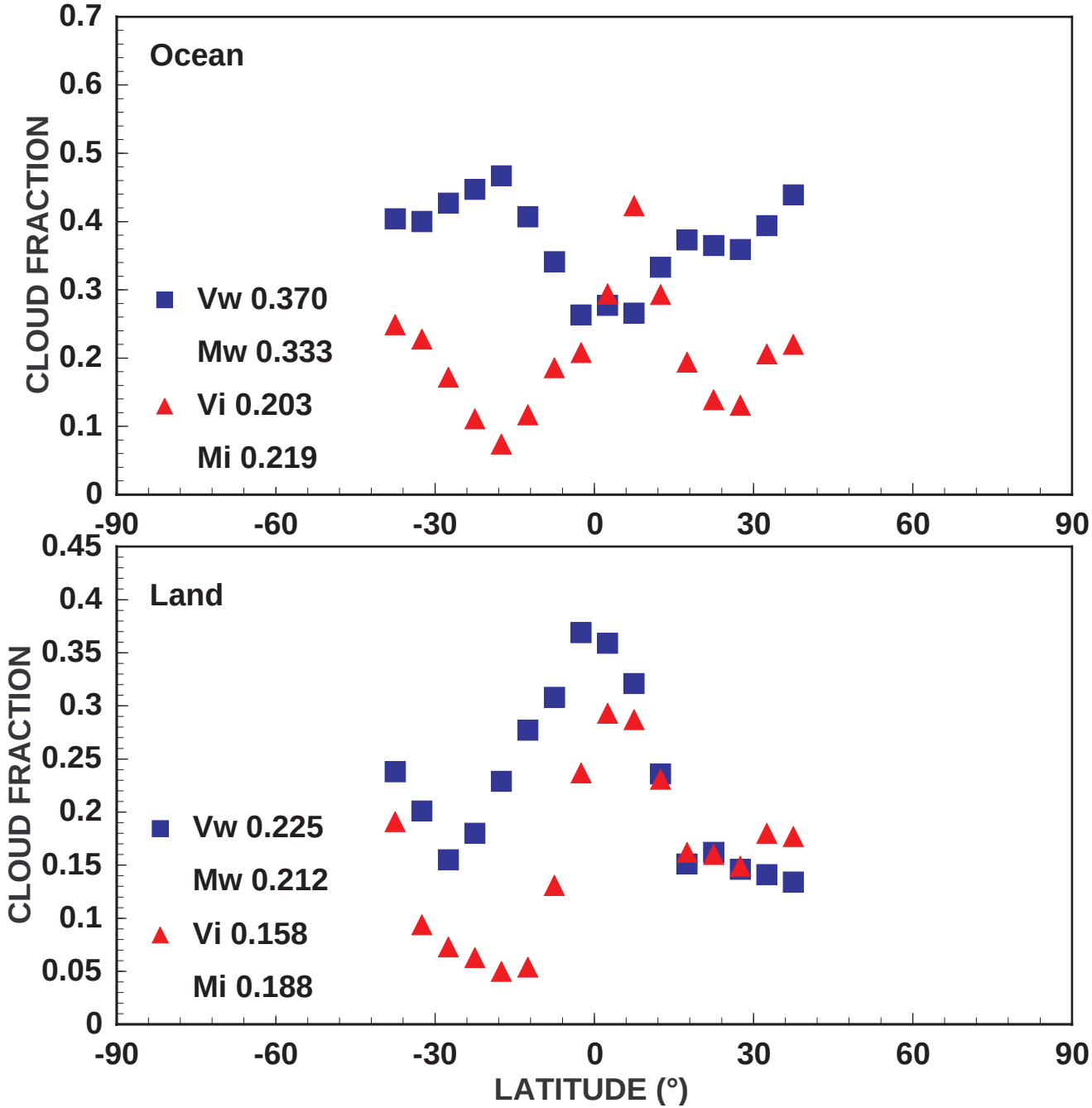
Cloud fraction, June 2001, MODIS (day 1 - 16) vs. VIRS (month)

V = VIRS
M = MODIS
O = Ocean
L = Land
T = total

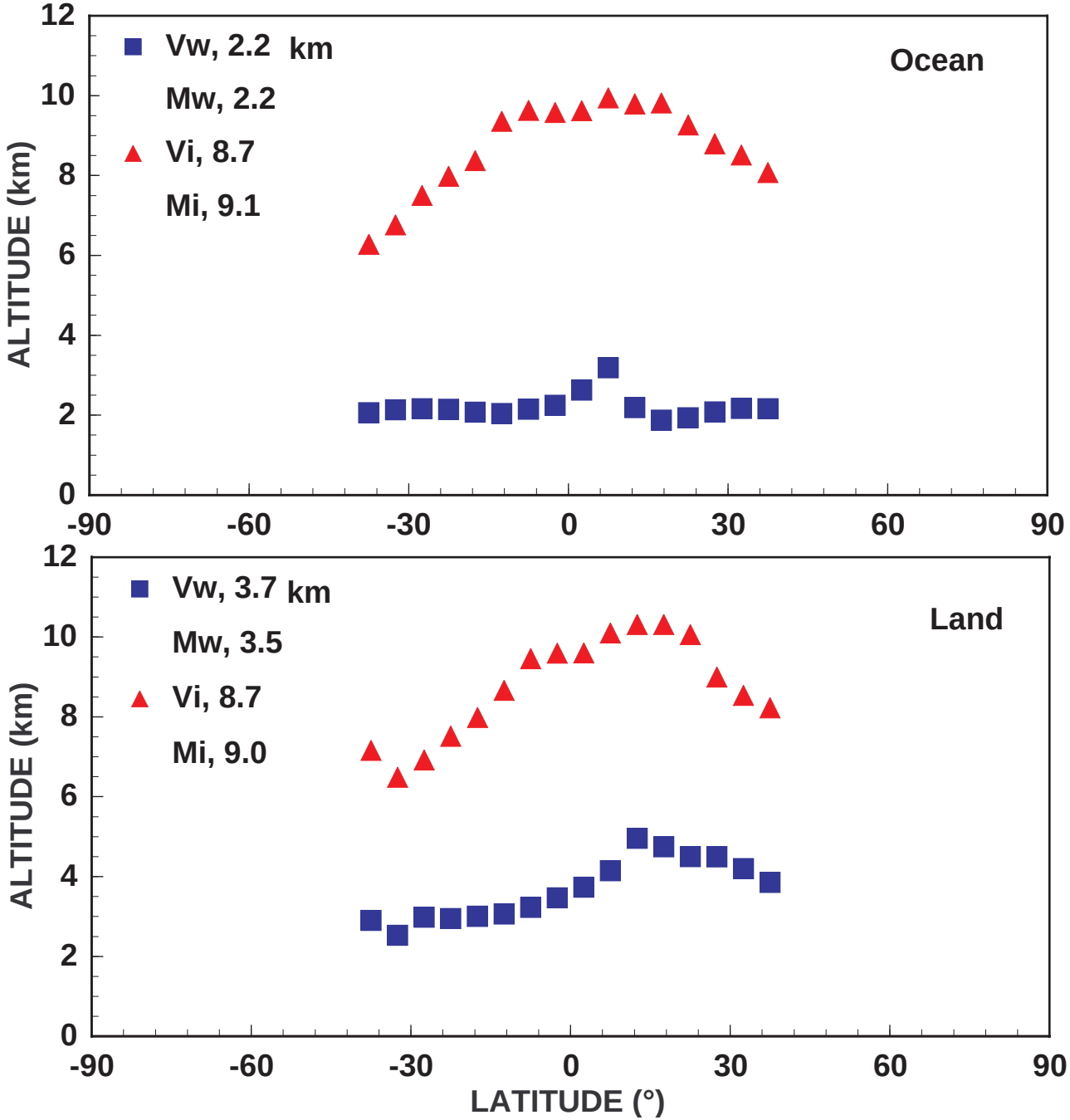


Cloud phase, June 2001, MODIS (day 1-16) vs. VIRS (month)

V = VIRS
M = MODIS
O = Ocean
L = Land
w = water
i = ice

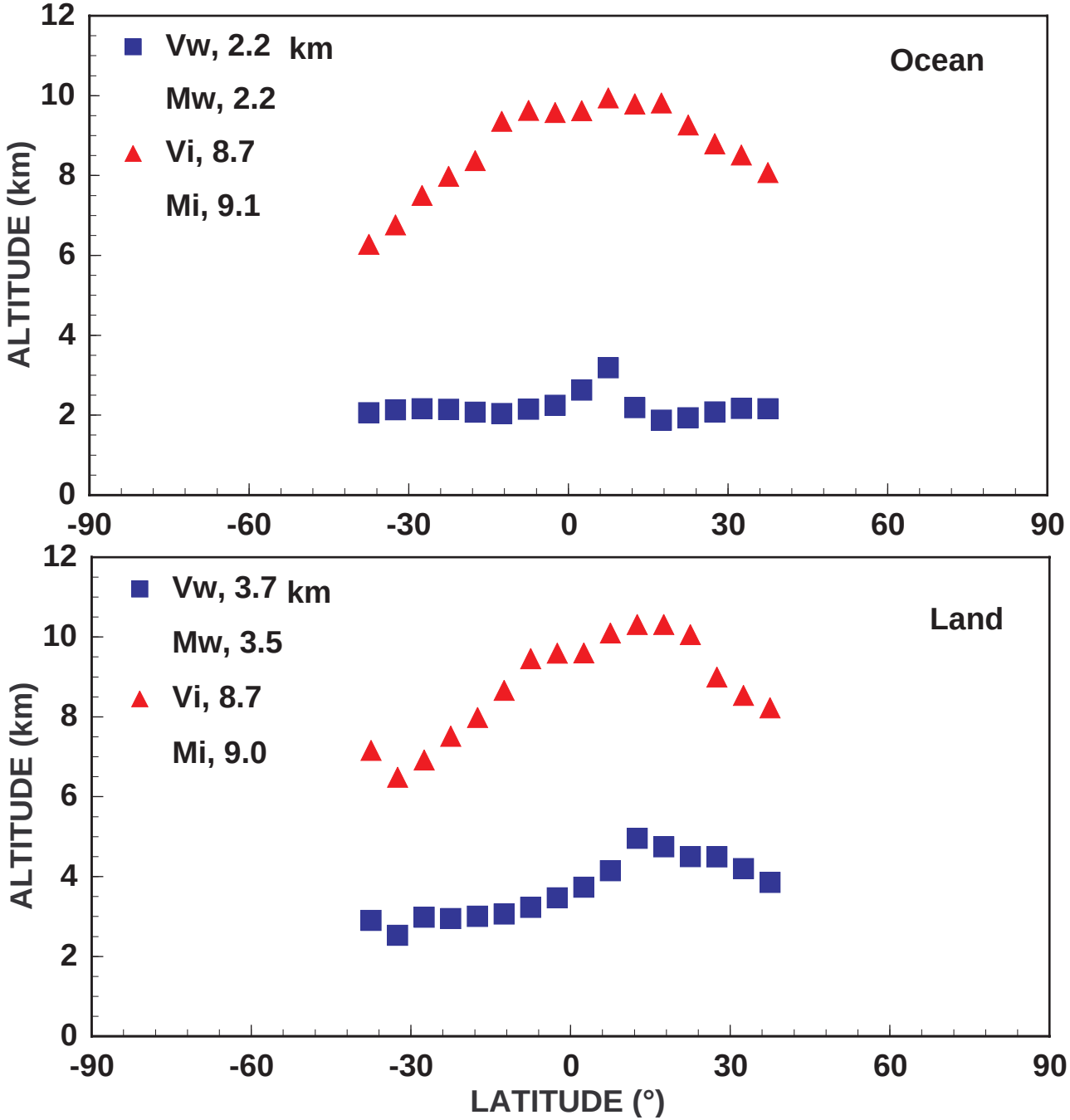


Cloud heights, June 2001, MODIS (1 -16) vs. VIRS (month)



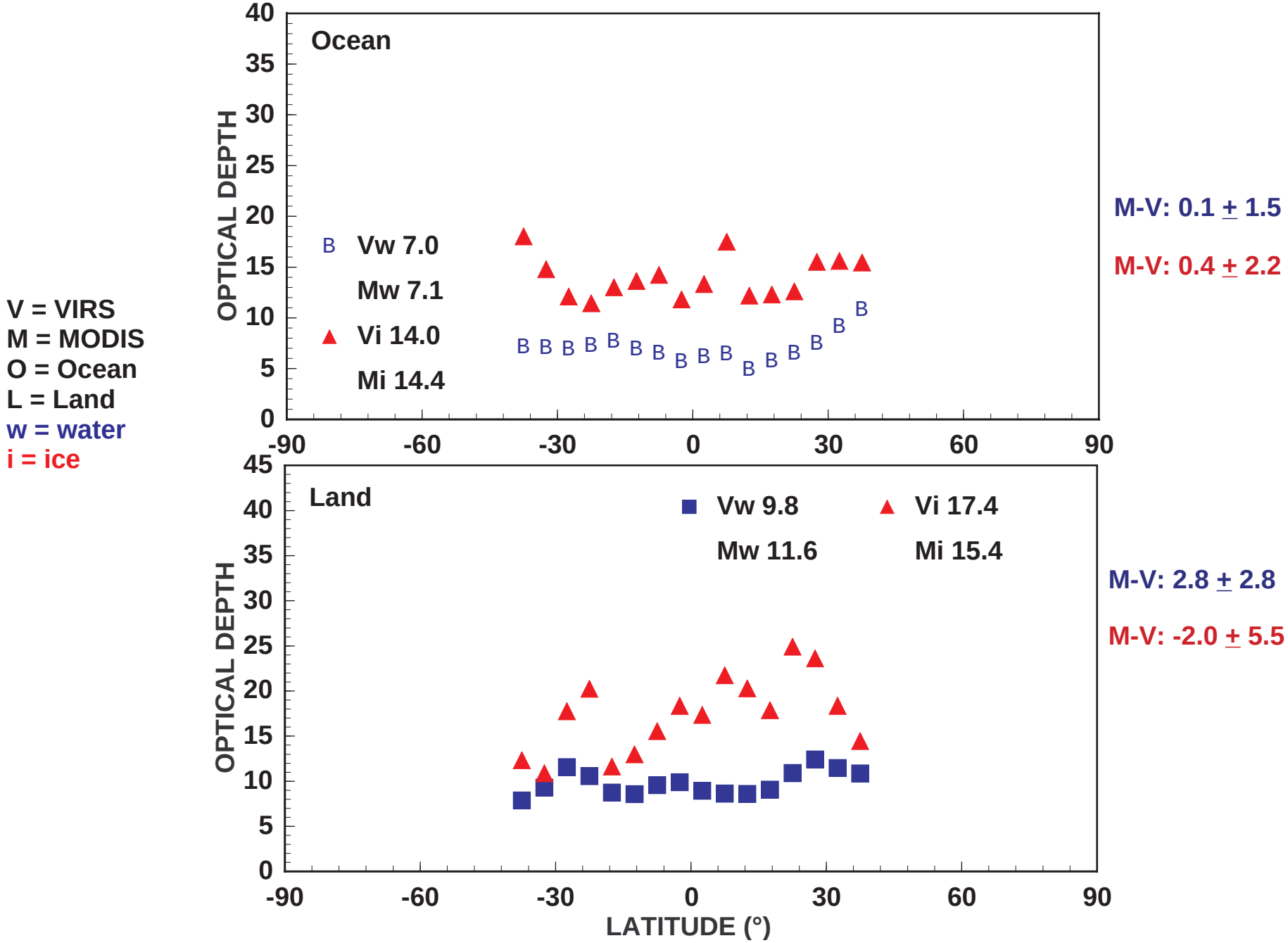
V = VIRS
M = MODIS
O = Ocean
L = Land
w = water
i = ice

Cloud heights, June 2001, MODIS (1 -16) vs. VIRS (month)



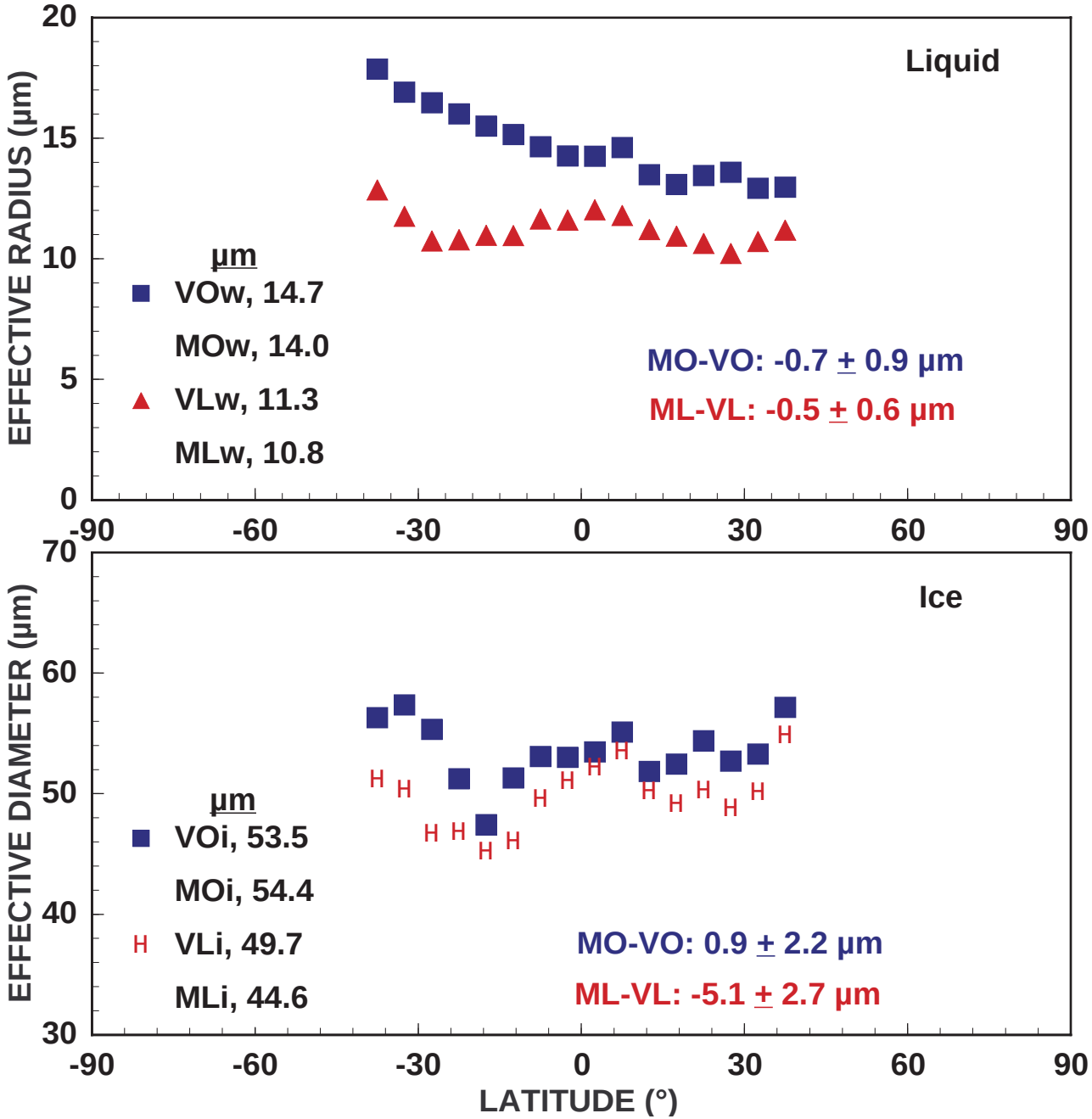
V = VIRS
M = MODIS
O = Ocean
L = Land
w = water
i = ice

Cloud optical depth, June 2001, MODIS (week 1) vs. VIRS (month)

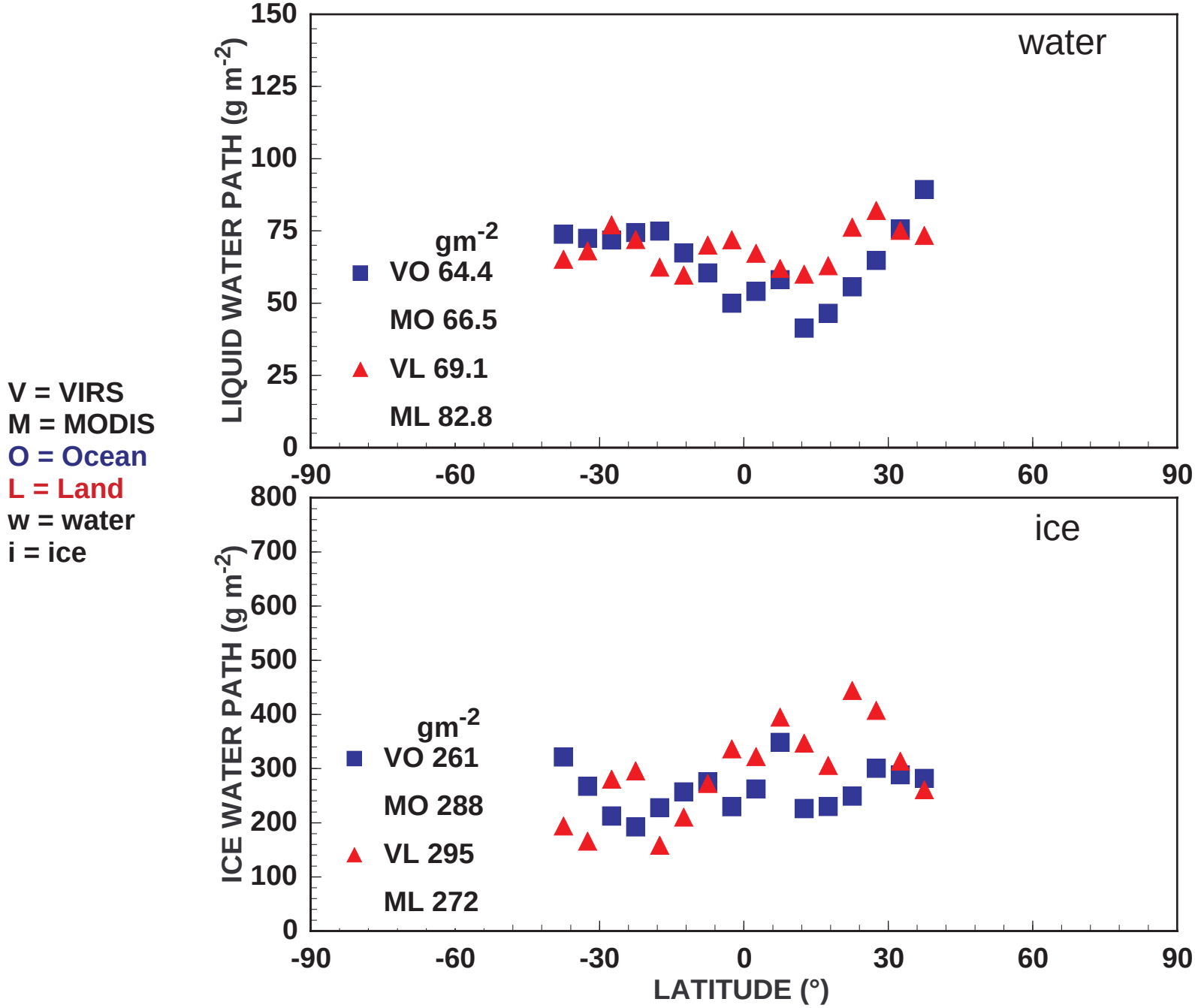


Cloud particle sizes, June 2001, MODIS (week 1) vs. VIRS (month)

V = VIRS
M = MODIS
O = Ocean
L = Land
w = water
i = ice



Cloud water path, June 2001, MODIS (1 - 16) vs. VIRS (month)



SUMMARY

- Cloud amount: **VIRS detects more cloud cover**

  - orbit times (MODIS designed for clear sky)

  - resolution differences, slight mask differences

- Optical depth: **VIRS has variable agreement with MODIS**

  - MODIS slightly greater on average (calibration, resolution), < 10% mean diff

- Effective size: **VIRS generally larger than MODIS (ice over land greatest)**

  - 0.5K difference in 3.7-µm cal => 0.5 µm Δre (< 10% bias)

  - Need updated 3.7-µm emissivity maps for thin clouds

- Water path: **Mixed results, < 10% difference on average, sampling differences**

- Heights: **Small differences on average, -0.2 km to 0.4 km (ice)**

- **Future: examine calibration differences more closely & impact of cloud emittance models & surface emissivity data**

NOTES

- VARIETY OF PROBLEMS IDENTIFIED

  SOME SOLVED

  OTHERS AWAIT SOLUTION

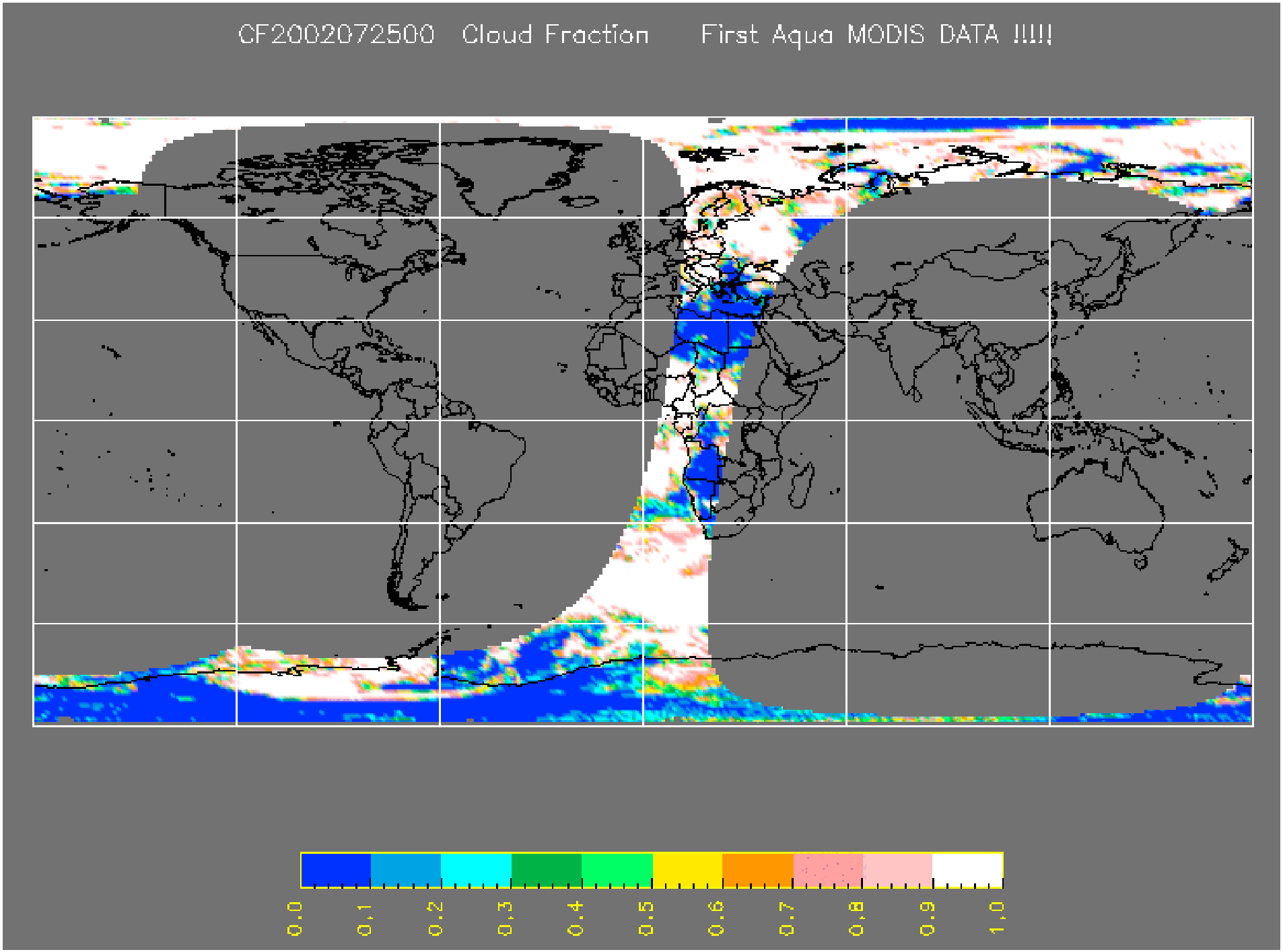
  NIGHTTIME IS BIGGEST PROBLEM AREA

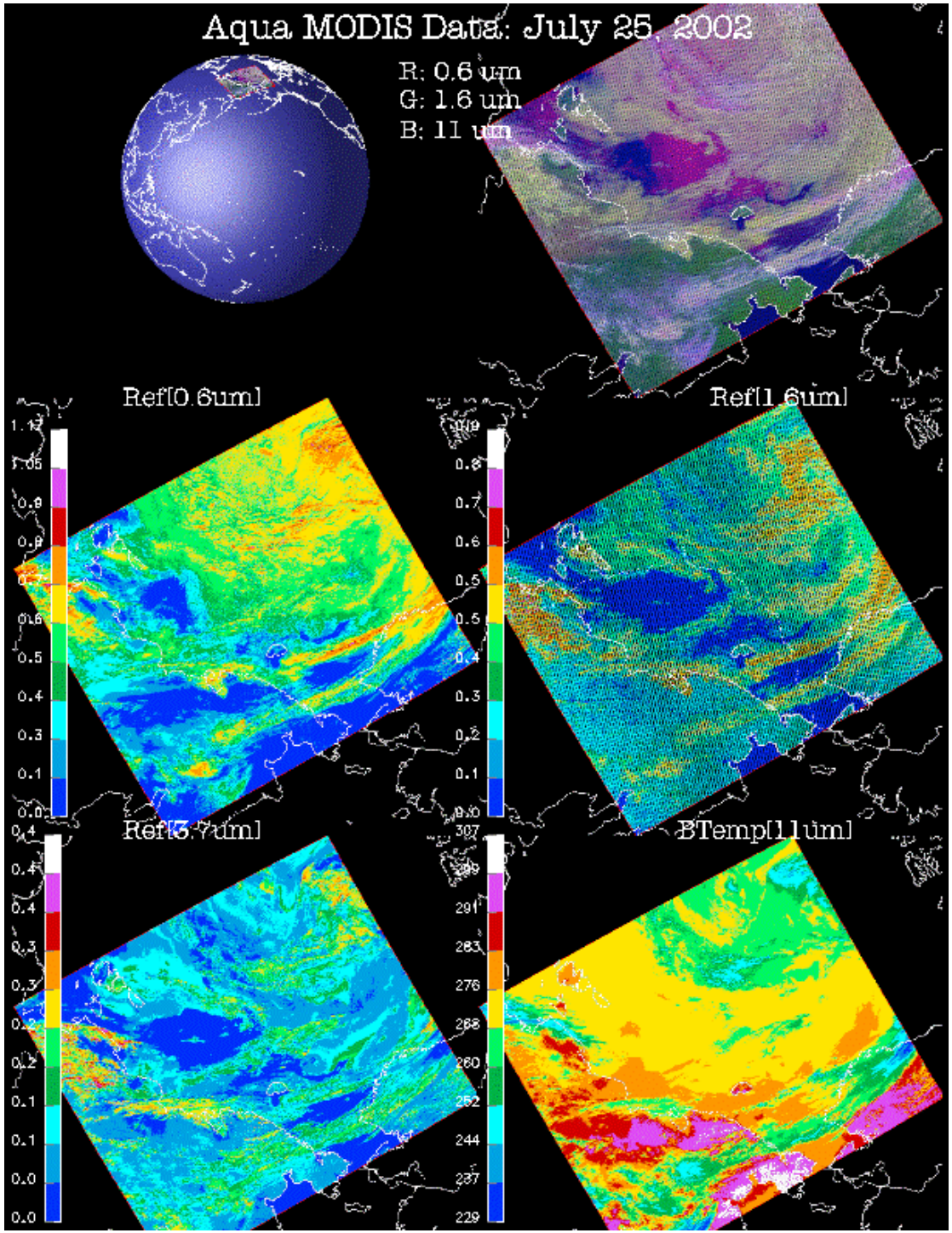
  ADMS & FLUXES PROBABLY NOT AFFECTED MUCH

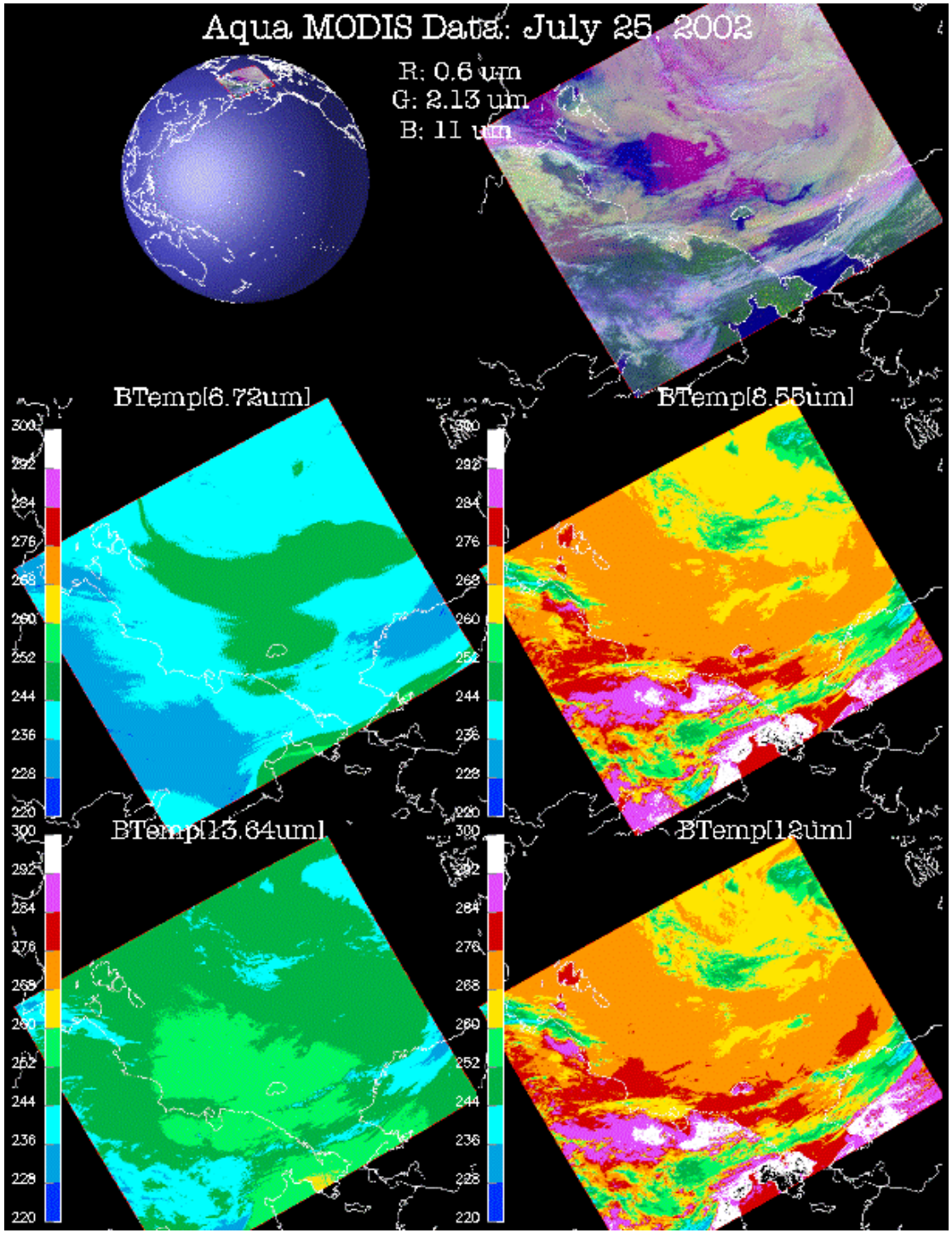
=> GO AHEAD AND RELEASE VERSION 1A

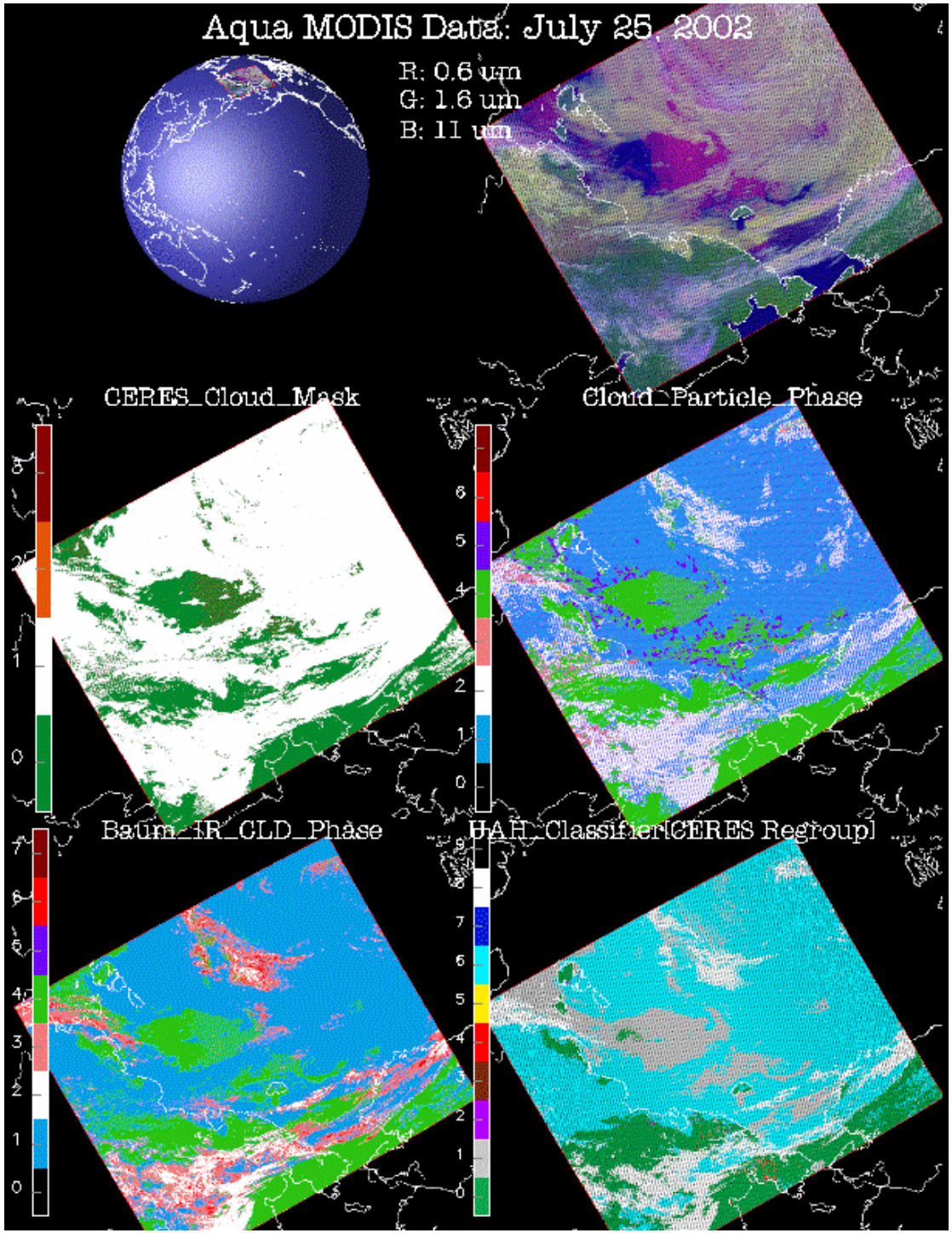
- CONTINUE WORKING ON SOLUTIONS

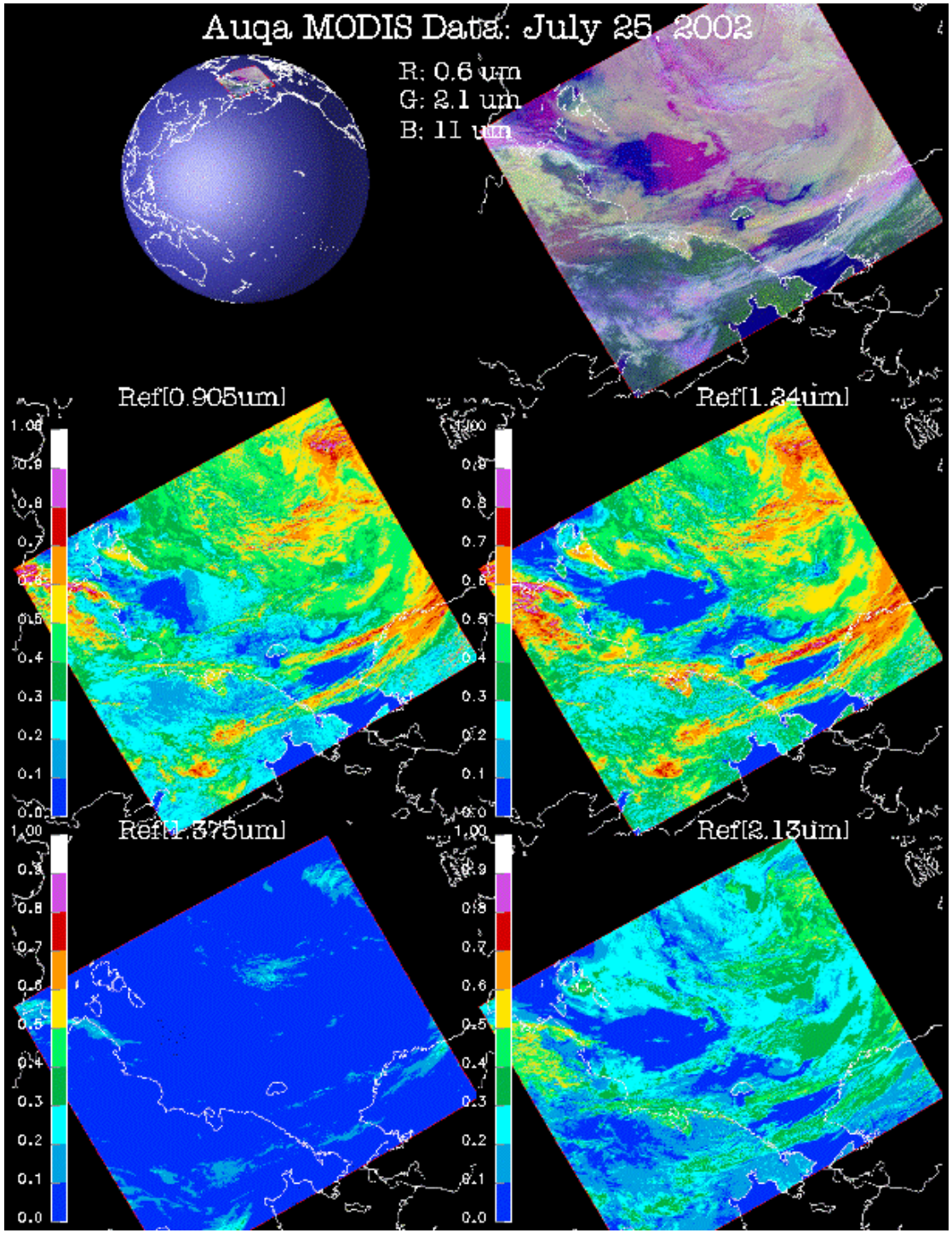
  HOPE FOR OPPORTUNITY TO MAKE LATER CHANGES

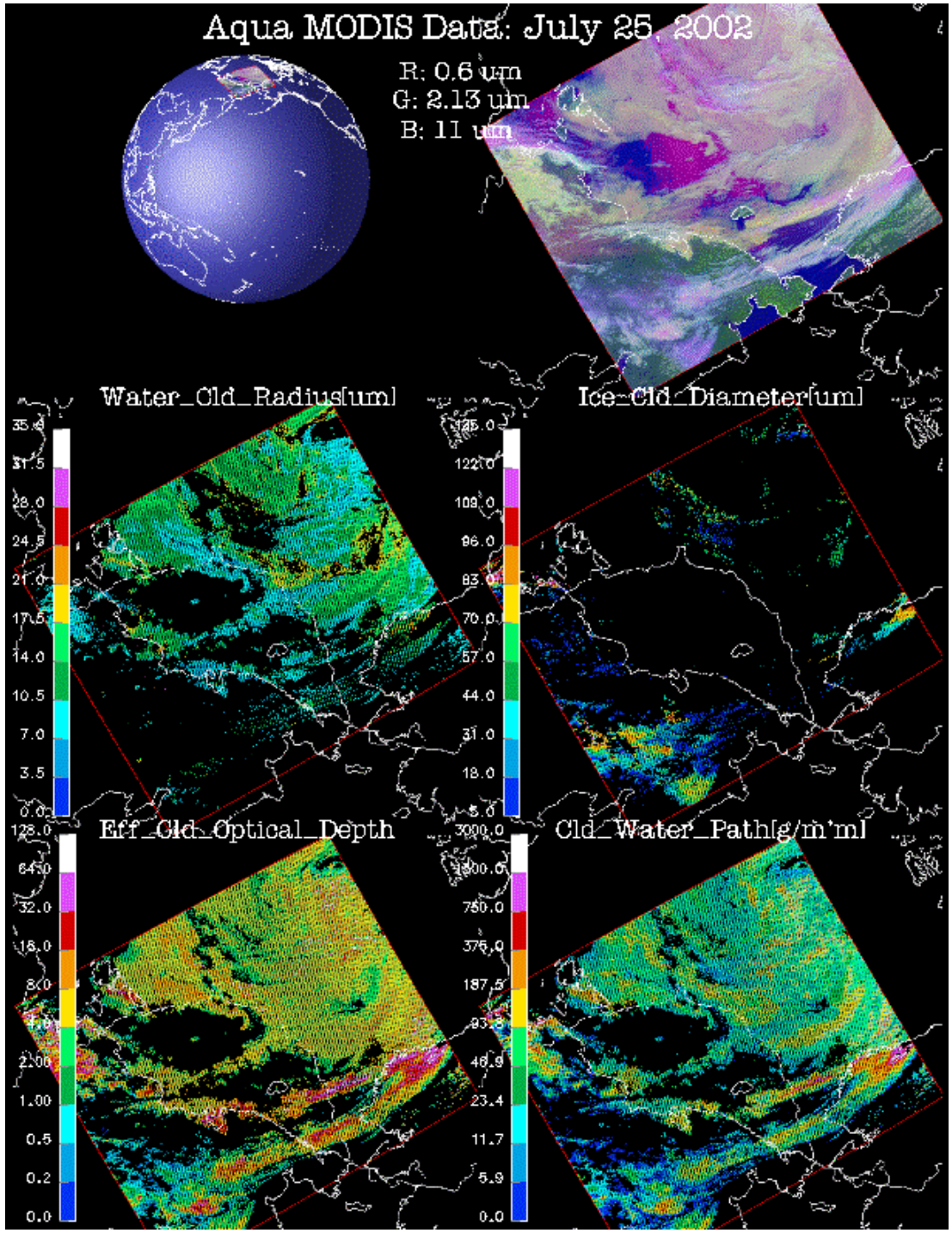

CF2002072500 Cloud Fraction First Aqua MODIS DATA !!!!!
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

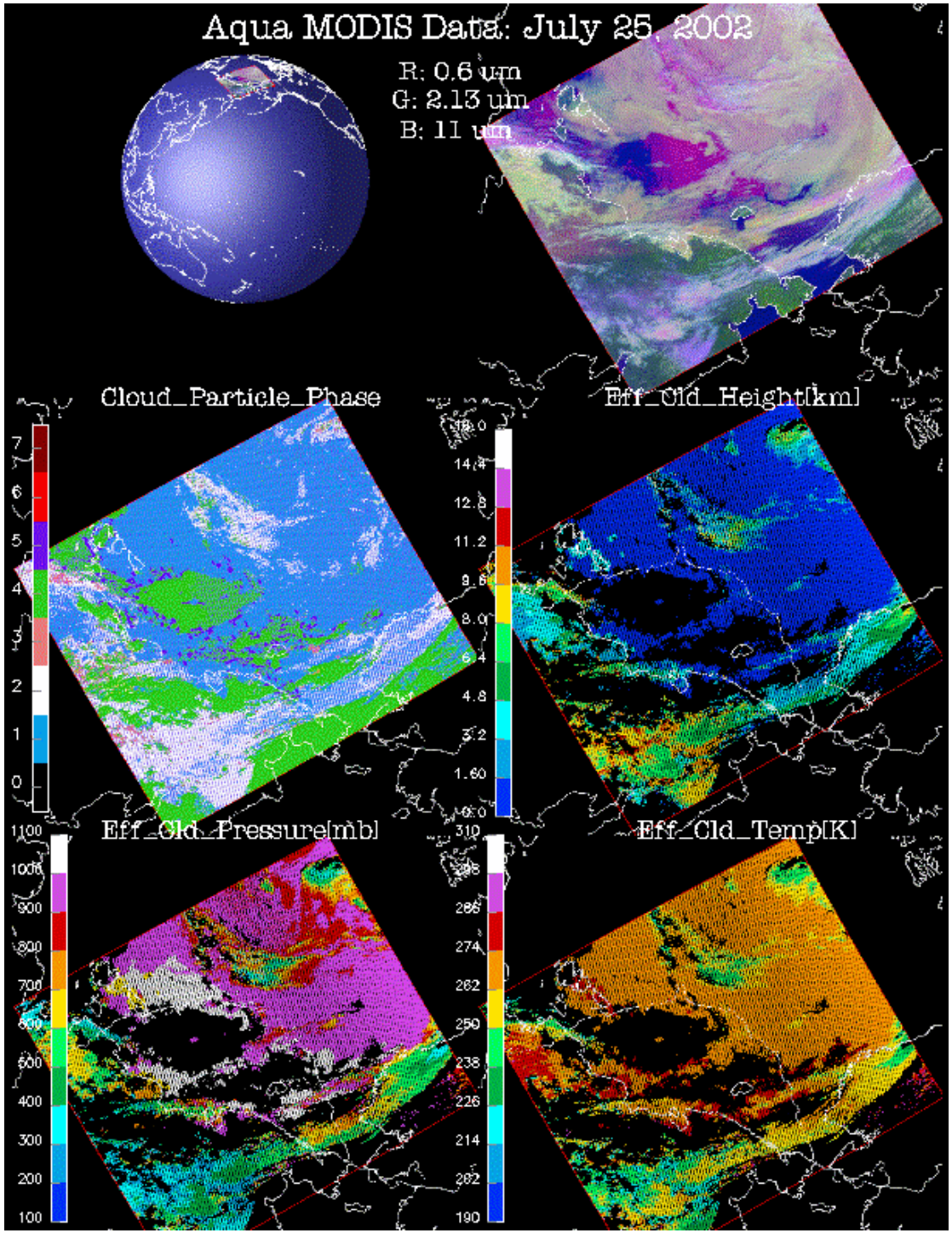

Aqua MODIS Data: July 25, 2002
R: 0.6 um
G: 1.6 um
B: 11 um
Ref[0.6um]
Ref[1.6um]
Ref[3.7um]
BTemp[11um]


Aqua MODIS Data: July 25, 2002
R: 0.6 um
G: 2.13 um
B: 11 um
BTemp[6.72um]
BTemp[8.55um]
BTemp[13.64um]
BTemp[12um]
300
292
284
276
268
260
252
244
236
228
220


Aqua MODIS Data: July 25, 2002
R: 0.6 um
G: 1.6 um
B: 11 um
CERES_Cloud_Mask
Cloud_Particle_Phase
Baum_IR_CLD_Phase
UAH_Classifier(CERES Regroup)


Auqa MODIS Data: July 25, 2002
R: 0.6 um
G: 2.1 um
B: 11 um
Ref[0.905um]
Ref[1.24um]
Ref[1.375um]
Ref[2.13um]


Aqua MODIS Data: July 25, 2002
R: 0.6 um
G: 2.13 um
B: 11 um
Water_Cld_Radius[um]
35.0
31.5
28.0
24.5
21.0
17.5
14.0
10.5
7.0
3.5
0.0
Ice_Cld_Diameter[um]
125.0
122.0
109.0
96.0
83.0
70.0
57.0
44.0
31.0
18.0
5.0
Eff_Cld_Optical_Depth
128.0
64.0
32.0
16.0
8.0
4.0
2.00
1.00
0.5
0.2
0.0
Cld_Water_Path[g/m^m]
3000.0
1500.0
750.0
375.0
187.5
93.8
46.9
23.4
11.7
5.9
0.0


Aqua MODIS Data: July 25, 2002
R: 0.6 um
G: 2.13 um
B: 11 um
Cloud_Particle_Phase
7
6
5
4
3
2
1
0
Eff_Cld_Height[km]
14.4
12.8
11.2
9.6
8.0
6.4
4.8
3.2
1.60
Eff_Cld_Pressure[mb]
1100
1000
900
800
700
600
500
400
300
200
100
Eff_Cld_Temp[K]
310
298
286
274
262
250
238
226
214
202
190

SUMMARY OF PRELIMINARY AQUA MODIS ANALYSES

- MODIS CHANNELS LOOK CLEAN EXCEPT FOR 1.6 µm
  - SELECT OTHER CHANNEL (1.24 or 2.13 µm)
  - GATHER STATS & DEVELOP MODELS

- ALGORITHMS WORKED WITH NO PROBLEMS
  - NEED TO VERIFY CALIBRATIONS

- MORE TO COME