# *The Quality of Early MODIS TIR Channel Data and*

# *the Implications to the MODIS LST Product*

- Results of a field campaign over Mono Lake, CA, March 23 through April 4, 2000.

- Analysis of some special MODIS data sets over lakes covered with melting snow.

- Preliminary remarks on the calibration of MODIS TIR channel data.

- Implications to the MODIS LST product.

- *A field campaign over Mono Lake, CA, 3/23 - 4/4*
  - In-situ measurements:
    - Thirteen thermistor-data loggers deployed between buoys 1-5 through the period.
    - Four floating systems of IR thermometers deployed on clear-sky days during the Terra overpasses.
    - Radiosonde launched on clear-sky days during the Terra overpasses.
    - An IR camera tested with a tethered balloon at a height of 200m above the ground.
    - April 4 was the golden date for the Mono Lake area, but there were broken clouds over Lake Tahoe.
  - A scheduled ER-2 MAS/AVIRIS flight over Mono Lake and Lake Tahoe was canceled due to technical problems.

- A summary of the results at the MODIS overpass, 19:15 UTC (11:15 PST), 4 April, 2000:

    — The MODIS LST value at buoy 5 is 285.9 °K.

    — After emissivity correction, the lake surface temperature measured by the IR thermomter is 284.7 °K.

    — The averaged water temperature measured by thermistors 1-2cm beneath the surface around buoy 5 is 285.4 °K.

    — A comparison between brightness temperatures of MODIS TIR bands and the calculated values based on the IR thermomter measured temperature and the measured atmospheric temperature and water vapor profiles is shown in Table 1.

*TABLE 1.*  A comparison between $T_b$ values of MODIS TIR bands and those calculated from measured $T_s$ and atmospheric profile.

| band | 20 | 21 | 22 | 23 | 24 | 25 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|
| MODIS $T_b$ (°K) | 287.12 | 281.72 | 284.97 | 282.55 | 251.49 | 267.95 | 250.09 | 265.18 |
| calculated $T_b$ | 283.12 | 282.83 | 282.92 | 281.44 | 250.85 | 266.12 | 254.14 | 265.84 |
| $\delta T_b$ (°K) | +3.62 | -1.11 | +2.05 | +1.11 | +0.64 | +1.83 | (-4.05) | (-0.66) |

| band | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|---|---|---|---|---|---|---|---|---|
| MODIS $T_b$ (°K) | 283.83 | 266.01 | 284.85 | 284.85 | 269.68 | 258.55 | 250.16 | 230.19 |
| calculated $T_b$ | 282.05 | 252.00 | 283.74 | 283.46 | 264.92 | 252.85 | 243.00 | 229.31 |
| $\delta T_b$ (°K) | +1.78 | (+14.0) | +1.01 | +0.74 | +4.76 | +5.70 | +7.16 | (+0.88) |

Note: solar radiation was not included in the calculations, values in () are too sensitive to values of water vapor, ozone, and upper level temperatures.

- *Analysis of some special MODIS data sets over lakes covered with melting snow.*
  - — The first special MODIS data set is MODIS granule ID A2000095.0055 over a sub-area (10 lines by 5 pixels) of a lake near Kamchatka, Russia in clear-sky condition. The snowcover in the MOD10_L2 product in the sub-area is 100, indicating snow melting ($T_S = 273.15\,^{\circ}K$). Atmospheric temperature and water vapor profile measured by a nearby weather station at 00:00 UTC.
  - — A comparison between brightness temperatures of MODIS TIR bands and the calculated values based on the estimated temperature and the measured atmospheric temperature and water vapor profiles is shown in Table 2.

*TABLE 2.* A comparison between $T_b$ values of MODIS TIR bands and those calculated from estimated $T_s$ and measured atmospheric profile.

| band | 20 | 21 | 22 | 23 | 24 | 25 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|
| MODIS $T_b$ (°K) | 276.19 | 274.21 | 273.46 | 271.18 | 243.50 | 257.47 | 238.70 | 253.47 |
| calculated $T_b$ | 272.02 | 271.50 | 271.59 | 270.23 | 243.91 | 256.85 | 234.42 | 250.61 |
| $\delta T_b$ (°K) | +4.17 | +2.71 | +1.87 | +0.95 | -0.41 | +0.62 | (+4.28) | (+2.86) |

| band | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|---|---|---|---|---|---|---|---|---|
| MODIS $T_b$ (°K) | 272.38 | 251.86 | 272.76 | 272.30 | 260.07 | 250.75 | 244.25 | 230.69 |
| calculated $T_b$ | 270.55 | 245.01 | 271.87 | 270.85 | 256.31 | 246.41 | 238.21 | 226.74 |
| $\delta T_b$ (°K) | +1.83 | (+6.85) | +0.89 | +1.45 | +3.76 | +4.35 | +6.04 | (+3.95) |

Note: solar radiation was not included in the calculations, values in () are too sensitive to values of water vapor, ozone, and upper level temperatures. The calculated Tb(32) is sensitive to snow emissivity.

- More special special MODIS data sets are found over Lake Nipigon, Canada, and Hovsgol Huur (lake), Mongolia.  But the standard deviation in MODIS $T_b$ values are larger probably due to variations in atmospheric and surface conditions.

- Quality analysis for all TIR channels in the first special MODIS data set is shown in Tables 3.1 and 3.2.
    — Noisy channels: the 9th channels in bands 21 and 24, and the 4th channel in band 22.
    — After skipping these noisy channels: variations are small for all bands except band 21.
    — The maximum difference of $T_b$ in all 50 pixels in band 31 is 0.24°K, indicating the uniform condition of the target area, and the good quality of band 31.

```
MOD_PR11sub_16b_stat.v1.1.exe A2000104.0055  (10 by 5 pixels)
 land/seamask = 3 for all pixels          height = 15m
 snowcover=100 for all 500m pixels        a lake by Kamchatka


band   20      21      22      23      24      25      27      28
npix     50      50      50      50      50      50      50      50
avg  276.19 268.75 273.97 271.19 243.07 257.47 238.70 253.47
min  275.80 196.80 273.16 270.90 220.20 256.52 238.26 253.22
max  276.90 278.00 281.76 271.56 253.54 257.84 239.38 253.68
std   0.305 17.512  1.675  0.163  4.053  0.347  0.282  0.096
    ( 0.043  2.477  0.237  0.023  0.573  0.049  0.040  0.014 )
avg_chan - avg_band
 0  -0.254   7.612 -0.682 -0.251  0.870 -0.236  0.169 -0.213
 1  -0.202   5.540 -0.606 -0.091  0.406  0.140 -0.063 -0.029
 2  -0.054   4.936 -0.506 -0.059 -0.350  0.196 -0.059 -0.013
 3  -0.218   6.112  4.582 -0.119  0.890 -0.064 -0.035 -0.029
 4  -0.142   4.668 -0.617 -0.059  0.482  0.128 -0.043 -0.029
 5  -0.218   5.532 -0.766 -0.071  0.546  0.360 -0.379  0.011
 6   0.002   4.940 -0.510  0.109  0.818  0.188 -0.163  0.067
 7   0.214   5.832 -0.294  0.069  0.790  0.284 -0.299  0.127
 8   0.422 -49.152 -0.329  0.165 -3.866 -0.860  0.605  0.095
 9   0.446   3.984 -0.274  0.305 -0.582 -0.132  0.265  0.015
std_chan
 0   0.108   1.059  0.065  0.062  0.098  0.084  0.064  0.036
 1   0.073   1.184  0.068  0.032  0.069  0.052  0.113  0.029
 2   0.091   1.504  0.065  0.071  0.179  0.050  0.099  0.036
 3   0.024   0.879  2.102  0.032  0.136  0.082  0.084  0.032
 4   0.113   1.118  0.051  0.029  0.141  0.097  0.054  0.039
 5   0.116   1.155  0.030  0.037  0.156  0.024  0.083  0.037
 6   0.212   1.480  0.069  0.037  0.176  0.101  0.055  0.036
 7   0.270   0.560  0.067  0.072  0.232  0.065  0.073  0.057
 8   0.227  18.985  0.097  0.089 12.046  0.117  0.045  0.016
 9   0.251   1.626  0.109  0.066  0.195  0.117  0.070  0.035


band   29      30      31      32      33      34      35      36
npix     50      50      50      50      50      50      50      50
avg  272.38 251.86 272.76 272.30 260.07 250.75 244.25 230.69
min  272.06 251.48 272.64 272.02 258.28 249.60 243.42 229.78
max  272.52 252.68 272.88 272.52 260.52 252.00 245.32 231.90
std   0.106  0.257  0.043  0.120  0.508  0.657  0.421  0.447
    ( 0.015  0.036  0.006  0.017  0.072  0.093  0.060  0.063 )
avg_chan - avg_band
 0  -0.297  0.709  0.009  0.114 -1.442  0.722  0.826  0.795
 1   0.003 -0.135  0.017  0.046  0.210  0.366  0.210  0.075
 2   0.023 -0.203  0.005  0.014  0.206  0.462  0.050 -0.253
 3   0.011 -0.007  0.009  0.074  0.190  0.290  0.002 -0.197
 4   0.095 -0.091  0.017  0.062  0.270  0.914 -0.002 -0.677
 5   0.067 -0.031  0.021  0.042  0.310 -0.898 -0.414 -0.157
 6   0.035 -0.067  0.005  0.034  0.106 -0.818 -0.302  0.187
 7   0.015 -0.071 -0.019 -0.098  0.214 -0.850  0.138  0.039
 8   0.007 -0.091 -0.039 -0.158 -0.054 -0.242  0.026  0.139
 9   0.043 -0.011 -0.023 -0.130 -0.010  0.058 -0.534  0.047
std_chan
 0   0.013  0.093  0.039  0.059  0.199  0.211  0.163  0.236
 1   0.013  0.054  0.033  0.052  0.083  0.165  0.251  0.263
 2   0.013  0.126  0.010  0.062  0.085  0.191  0.185  0.353
 3   0.027  0.027  0.010  0.029  0.144  0.048  0.130  0.302
 4   0.035  0.037  0.000  0.029  0.135  0.192  0.201  0.111
 5   0.023  0.090  0.059  0.078  0.073  0.196  0.319  0.207
 6   0.016  0.047  0.035  0.057  0.083  0.134  0.206  0.219
 7   0.037  0.101  0.008  0.120  0.038  0.171  0.277  0.085
 8   0.041  0.130  0.032  0.111  0.151  0.137  0.270  0.286
 9   0.031  0.081  0.078  0.127  0.154  0.134  0.063  0.430
```

```
MOD_PR11sub_16b_stat.v1.1.exe A2000104.0055  (10 by 5 pixels)
 land/seamask = 3 for all pixels        height = 15m
 snowcover=100 for all 500m pixels      a lake by Kamchatka


band   20     21     22     23     24     25     27     28
npix   50     45     45     50     45     50     50     50
avg  276.19 274.21 273.46 271.19 243.50 257.47 238.70 253.47
min  275.80 270.30 273.16 270.90 242.24 256.52 238.26 253.22
max  276.90 278.00 273.84 271.56 244.18 257.84 239.38 253.68
std   0.305  1.558  0.182  0.163  0.534  0.347  0.282  0.096
   (  0.043  0.232  0.027  0.023  0.080  0.049  0.040  0.014 )
avg_chan - avg_band
 0  -0.254  2.150 -0.172 -0.251  0.440 -0.236  0.169 -0.213
 1  -0.202  0.078 -0.096 -0.091 -0.024  0.140 -0.063 -0.029
 2  -0.054 -0.526  0.004 -0.059 -0.780  0.196 -0.059 -0.013
 3  -0.218  0.650  skip  -0.119  0.460 -0.064 -0.035 -0.029
 4  -0.142 -0.794 -0.108 -0.059  0.052  0.128 -0.043 -0.029
 5  -0.218  0.070 -0.256 -0.071  0.116  0.360 -0.379  0.011
 6   0.002 -0.522 -0.000  0.109  0.388  0.188 -0.163  0.067
 7   0.214  0.370  0.216  0.069  0.360  0.284 -0.299  0.127
 8   0.422  skip   0.180  0.165  skip  -0.860  0.605  0.095
 9   0.446 -1.478  0.236  0.305 -1.012 -0.132  0.265  0.015
std_chan
 0   0.108  1.059  0.065  0.062  0.098  0.084  0.064  0.036
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 3   0.024  0.879  skip   0.032  0.136  0.082  0.084  0.032
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 4   0.095 -0.091  0.017  0.062  0.270  0.914 -0.002 -0.677
 5   0.067 -0.031  0.021  0.042  0.310 -0.898 -0.414 -0.157
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 6   0.016  0.047  0.035  0.057  0.083  0.134  0.206  0.219
 7   0.037  0.101  0.008  0.120  0.038  0.171  0.277  0.085
 8   0.041  0.130  0.032  0.111  0.151  0.137  0.270  0.286
 9   0.031  0.081  0.078  0.127  0.154  0.134  0.063  0.430
```
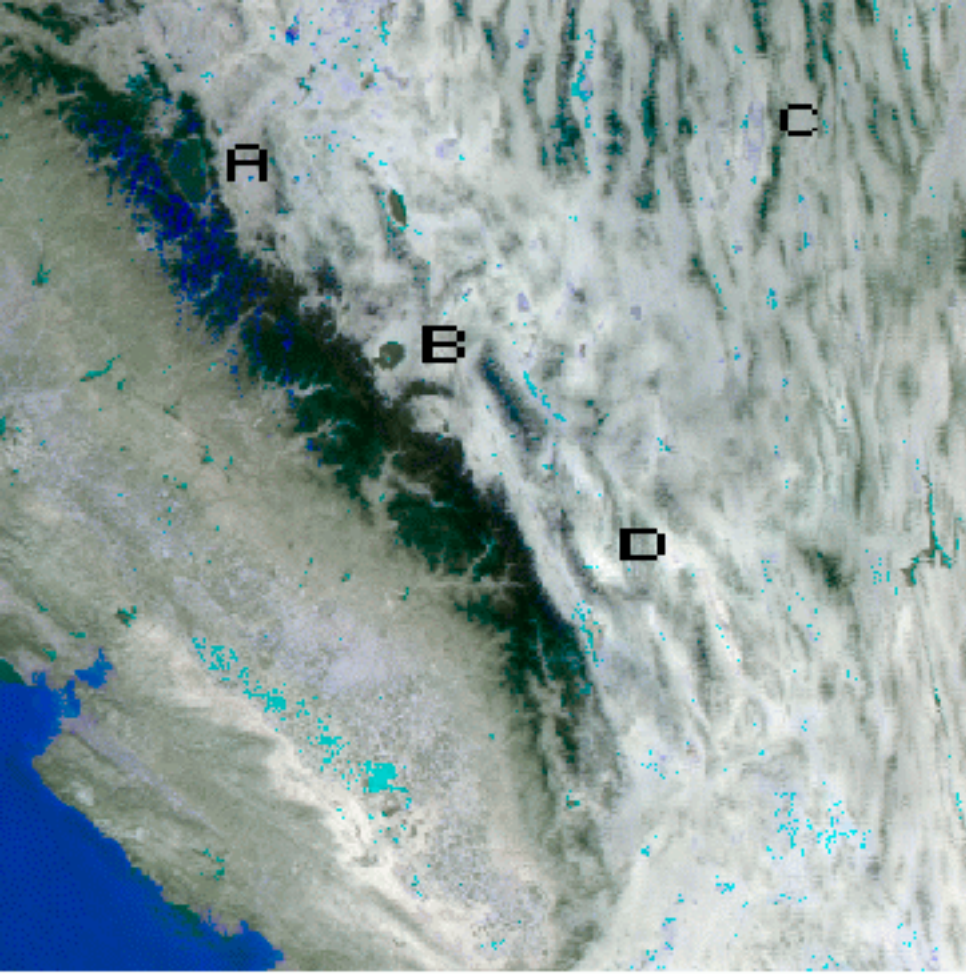
- *Preliminary remarks on the calibration of MODIS TIR channel data:*
    - — The noisy channels in bands 21-24 should be skipped in L2 processing.
    - — The calibration coefficients need to be improved.  The calibration error in bands 31 and 32 may be approximately 1°K.  Even worse for bands 33-35.

- *Implications to the MODIS LST product:*
  — The stripping can be reduced by correcting the cloudy pixels in channel 9th with its neighboring pixels in channels 8th and 10th.
  — The error in level-2 LST product generated from MODIS bands 31 and 32 may be slightly larger than $1°K$.
  — The quality of level-3 LST products generated by the day/night LST algorithm using seven TIR bands needs to investigate further.