An Assignment on

Estimating crop stress from remotely sensed Land-surface temperature (LST)

Prepared by

Mustafa Kamal Shahadat
Scientific Officer (agronomy)
Bangladesh Agricultural Research Institute
On-Farm Research Division, Khulna

Q. What is the difference between the satellite zenith angle and satellite-viewing angle (draw a picture to explain)?

Answer: The difference between satellite zenith angle and satellite viewing angle has been presented in the table below:

Table 1. Difference between satellite zenith angle and satellite viewing angle

Satellite Zenith Angle	Satellite Viewing Angle
The angle between a straight line from a point on the earth's surface to the satellite and a line from the same point on the earth's surface that is perpendicular to the earth's surface at that point (the zenith point).	The angle between the look direction from the satellite at nadir point and a straight line from a target on the earth's surface towards the satellite.
The zenith angle is the angle from the target point of view.	The viewing angle is the angle from the satellite point of view.

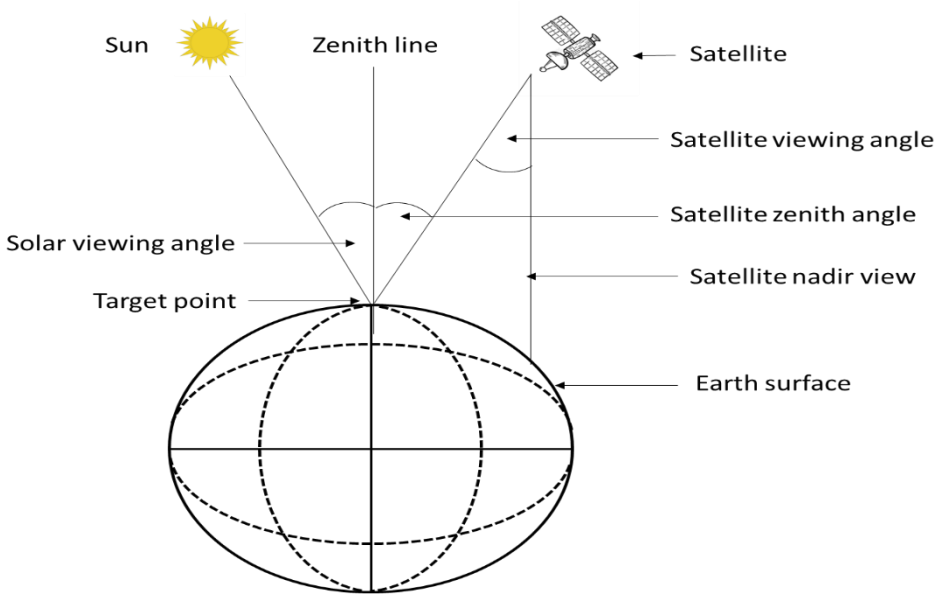

Figure 1. Illustration of Satellite zenith angle and satellite viewing angle

Figure 1 shows that satellite zenith angle is produced by the straight line from the target on the earth's surface to the satellite and a straight line perpendicular to the earth's surface at that target. On the contrary, the satellite viewing angle is the the look direction from the satellite at nadir point and a straight line from the target on the earth's surface towards the satellite.

Q. Calculate the local pixel for Quzhou (4867 km away from at-nadir). Is this acceptable given the heterogeneity of the maize land-use systems of this area?

Answer:

Satellite pixel size calculator

Legend

		POLAR-ORBIT		GEO-ORBIT	
satellite orbital params		NOAA/AVHRR	SPOT4/VEGETATION	GMS-5/VISSR IR	MSG-1/SEVIRI VS/IR
input	IFOV [resolution in km]=	1.1	1.165	5	3
output	IFOV [miliradians]=	1.279070	1.420731	0.136355	0.083799
	Satellite altitude [km]=	860	820	36669	35800
	Earth radius [km]=	6371	6371	6371	6371
	η [°]=	49.3	50.6	7.6	1.6
	Max. pixel size [km]=	5	0.5	5	5
	d [km]=	1000	1000	4867	1000
	α [°]=	120.62	119.22	117.27	169.35
	θ [°]=	59.38	60.78	62.73	10.65
	γ [°]=	10.07	10.14	55.17	9.05
	sat. elev. Ang. [°]=	30.62	29.22	27.27	79.35
	a [km]=	1.84	2.11	5.91	1.53
	b [km]=	0.94	1.03	2.71	1.50
	So-Sn [km]=	1120	1127	6135	1006
	Pixel sizes [km]				
	scan direction	3.69	4.22	11.83	3.06
	track direction	1.88	2.06	5.42	3.01
	average	**2.63**	**2.95**	**8.01**	**3.03**
			Warning!	Warning!	

The local pixel size for Quzhou (4867 km away from at-nadir) is 8.01 km using an excel formula for GMS-5/VISSR IR (Geostationary Meteorological Satellite).

Here the maximum pixel size for the satellite is 5 X 5 km^2 but the local pixel size for Quzhou is 8.01 km, as calculated from the excel formula. It is noted that there is a warning sign in the formula, which means there might be some mixed pixel. However, according to Venus and Rugege (2004) the experimental maize fields at Quzhou are homogenous Land Use Systems (>250 km^2), so there is hardly any chance of mixed pixel problem. If the land use system is heterogeneous with the local pixel size more than 5 km, there might be a problem of mixed pixel, which needs to be care about. So, in case of heterogeneity of the maize land-use system of Quzhou the local pixel size of 8.01 is not acceptable.

Q. Annotate the figure by adding the corresponding filenames (A_01, etc.) at the appropriate locations of the EO-processing diagram.

Answer:

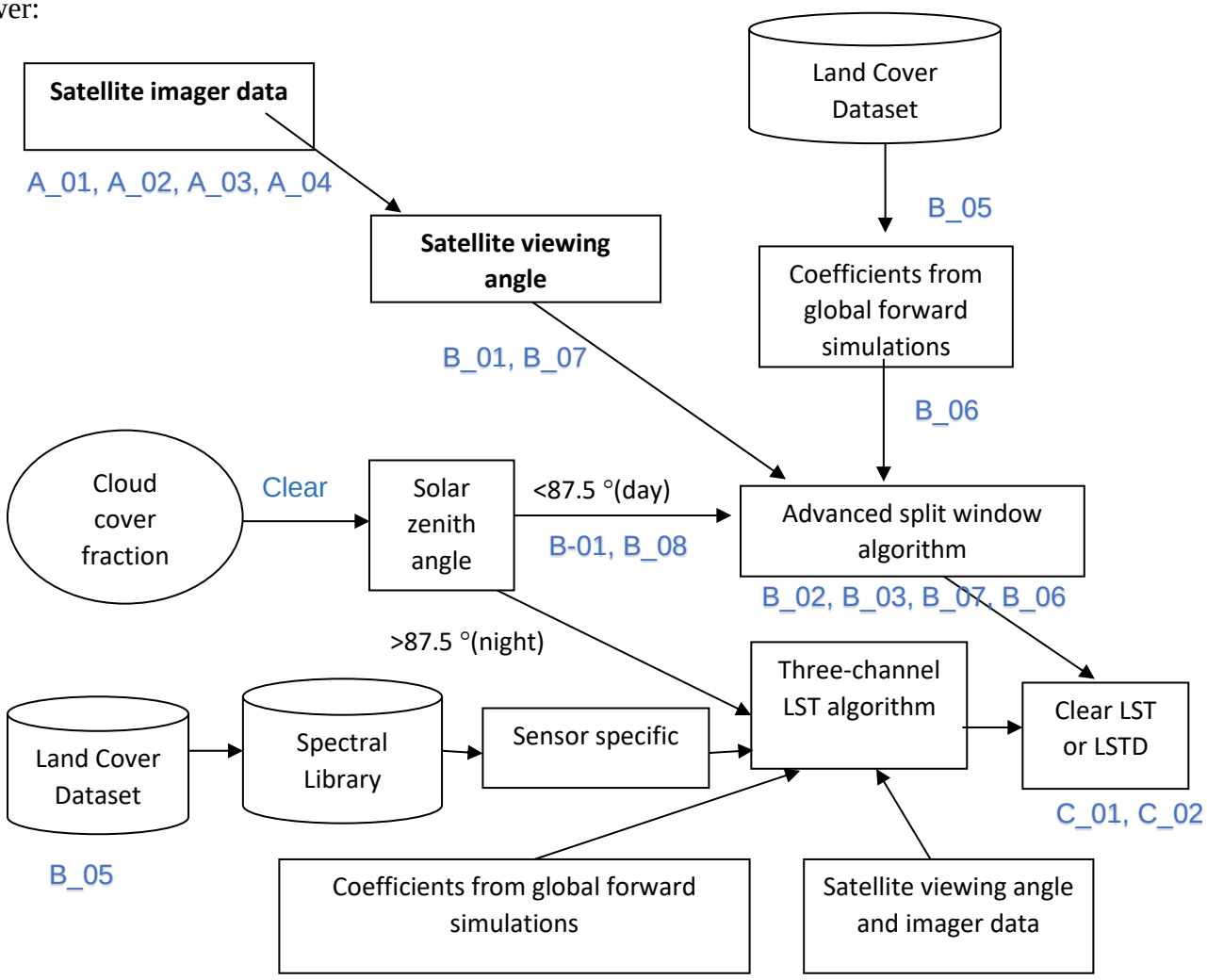

Figure 2. Flow diagram showing the major steps to derive land surface temperature (LST) from GMS-5

Q. Calculate the Land Surface Temperature (LST) from GMS-5 for 09/20/1999 06:00, 07:00 and 08:00.

According to the product C_00 of ILWIS software, LST values of 10 locations (maize research sites at Quzhou P.R. of China during 1999) have been retrieved from C_01 column (Table 2).

Table 2. Calculated LST of Quzhou research stations at 6:00, 7:00 and 8:00 UTC using GMS-5

Points	Location	GMS-5 6.00 (° k)	GMS-5 7.00 (° k)	GMS-5 8.00 (° k)
pnt 0	36°52'01.030"N,115°06'35.7200"E	300.2	300.7	300.8
pnt 1	36°52'00.000"N,115°00'00.0000"E	295.9	298.8	298.3
pnt 2	36°38'00.000"N,115°05'00.0000"E	298.8	290.2	285.9
pnt 3	36°42'00.000"N,115°53'00.0000"E	300.4	299.8	300.2
pnt 4	36°47'00.000"N,115°02'00.0000"E	301.5	295.5	292.3
pnt 5	36°49'00.000"N,115°58'00.0000"E	298.9	302.0	301.2
pnt 6	36°50'00.000"N,115°58'00.0000"E	298.9	302.0	301.2
pnt 7	36°43'00.000"N,115°52'00.0000"E	300.4	299.8	302.5
pnt 8	36°44'00.000"N,115°58'00.0000"E	300.4	300.1	299.3
pnt 9	36°46'00.000"N,115°57'00.0000"E	298.9	300.1	301.2
	Average	**299.43 °k**	**298.9 °k**	**298.29 °k**

Q. Is the temperature at the Quzhou research stations warmer or colder compared to 06:00 UTC (Coordinated Universal Time)?

The average temperature at Quzhou research stations was colder at 7:00 UTC (298.9 °k) and 8:00 UTC (298.29 °k) in comparison to 6:00 UTC (299.43 °k).

Q. Is it more commensurate with the NOAA/AVHRR 07:00 observation?

Table 3: Temperature of ten locations at Quzhou as per NOAA/AVHRR at 7:00 UTC

Points	Location	NOAA 7.00 (° k)
pnt 0	36°52'01.030"N,115°06'35.7200"E	298.7
pnt 1	36°52'00.000"N,115°00'00.0000"E	298.7
pnt 2	36°38'00.000"N,115°05'00.0000"E	297.1
pnt 3	36°42'00.000"N,115°53'00.0000"E	294.7
pnt 4	36°47'00.000"N,115°02'00.0000"E	298.6
pnt 5	36°49'00.000"N,115°58'00.0000"E	296.6
pnt 6	36°50'00.000"N,115°58'00.0000"E	296.6
pnt 7	36°43'00.000"N,115°52'00.0000"E	294.6
pnt 8	36°44'00.000"N,115°58'00.0000"E	297.1
pnt 9	36°46'00.000"N,115°57'00.0000"E	295.4
	Average	**296.81 °k**

The average LST according to GMS-5 during 06:00, 07:00 and 08:00 was 299.43 °k, 298.9 °k and 298.29 °k, respectively. The three hours average LST of GMS-5 was 298.87, while the average LST of NOAA was 296.81 °k. So, there was about 2°K higher LST in GMS-5 than NOAA. With respect to 7:00 UTC, the LST of NOAA (296.81 °k) is about 2°K lower than GMS-5 (298.9 °k) (Table 3).

Q. Are some previously cloud-contaminated pixels now populated with cloud free, reliable LST information to simulate crop yield stress periods more realistically?

Answer: At 6:00 UTC pixel point 7 and at 7:00 UTC pixel point 9 were cloud contaminated. But at 8:00 UTC both the pixel are now populated with cloud free (annotated in the figure 3, 4, 5) (Table 4).

Figure 3. **GMS-5 for 09/20/1999 at 06:00 UTC**

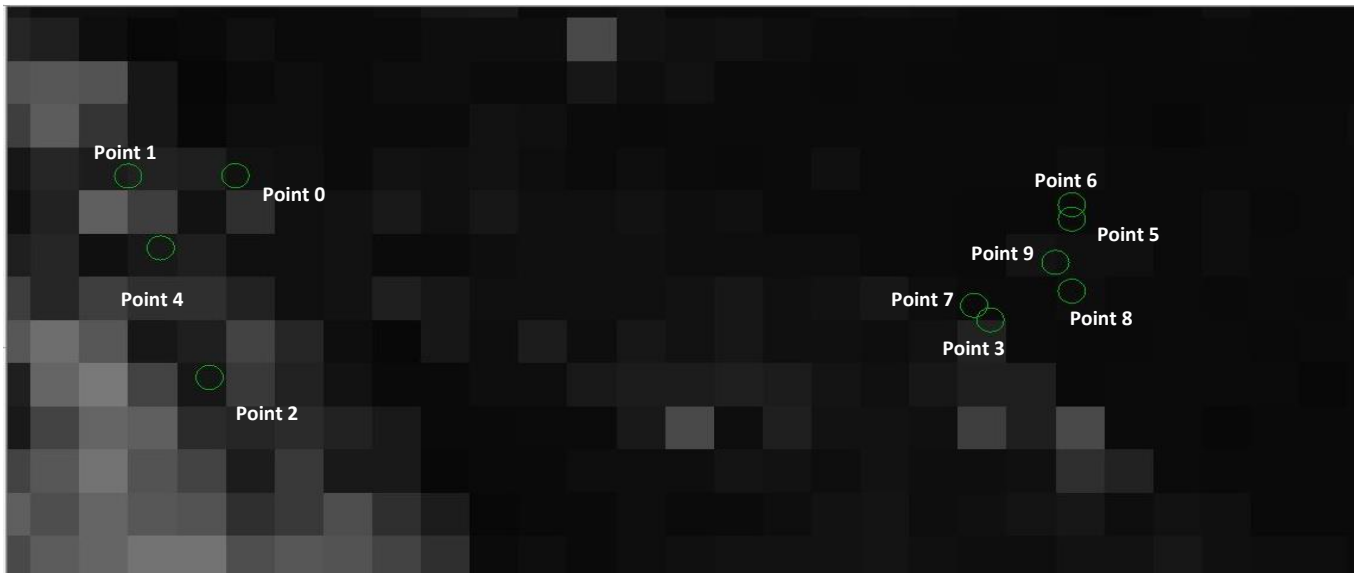

Figure 4. **GMS-5 for 09/20/1999 at 07:00 UTC**

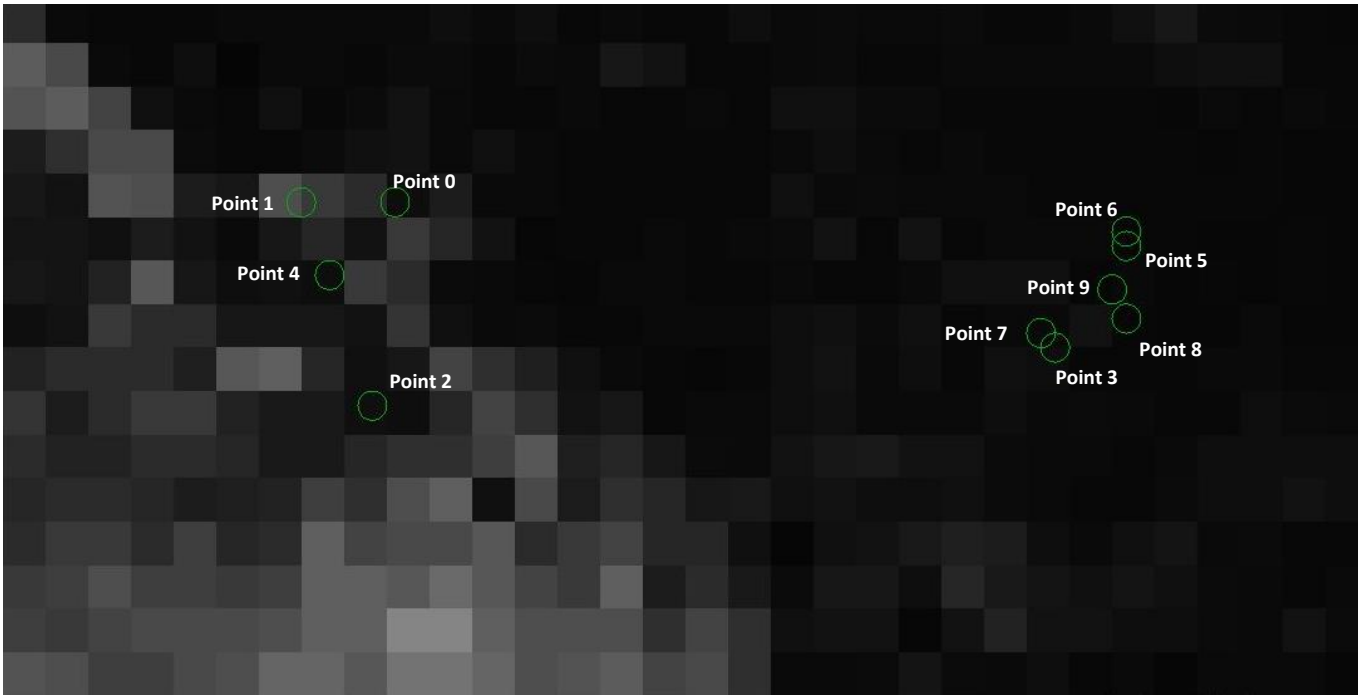

Figure 5. **GMS-5 for 09/20/1999 at 08:00 UTC**

Table 4. Hourly LST and cloud contamination scenarios

Points	GMS-5 6.00 (° k)	Cloudy situation	GMS-5 7.00 (° k)	Cloudy situation	GMS-5 8.00 (° k)	Cloudy situation
pnt 0	300.2	Without cloud	300.7	Slightly cloud	300.8	Slightly cloud
pnt 1	295.9	Fraction cloud	298.8	Lower Cloud	298.3	Higher Cloud
pnt 2	298.8	Without cloud	290.2	Without cloud	285.9	Without cloud
pnt 3	300.4	With cloud	299.8	With cloud	300.2	With cloud
pnt 4	301.5	Without cloud	295.5	Without cloud	292.3	Without cloud
pnt 5	298.9	Without cloud	302.0	Without cloud	301.2	Without cloud
pnt 6	298.9	Without cloud	302.0	Without cloud	301.2	Without cloud
pnt 7	**300.4**	**With cloud**	**299.8**	**Without cloud**	**302.5**	**Without cloud**
pnt 8	**300.4**	**Without cloud**	**300.1**	**Without cloud**	**299.3**	**Without cloud**
pnt 9	**298.9**	**Without cloud**	**300.1**	**With cloud**	**301.2**	**Without cloud**

Q. Calculate the maize production levels (water limited) for Quzhou, 1999 (using alternative water balance, *cfH2O*).

According to Polar orbiting satellite, grain yield of maize was 8178 kg ha^{-1} (Figure 6).

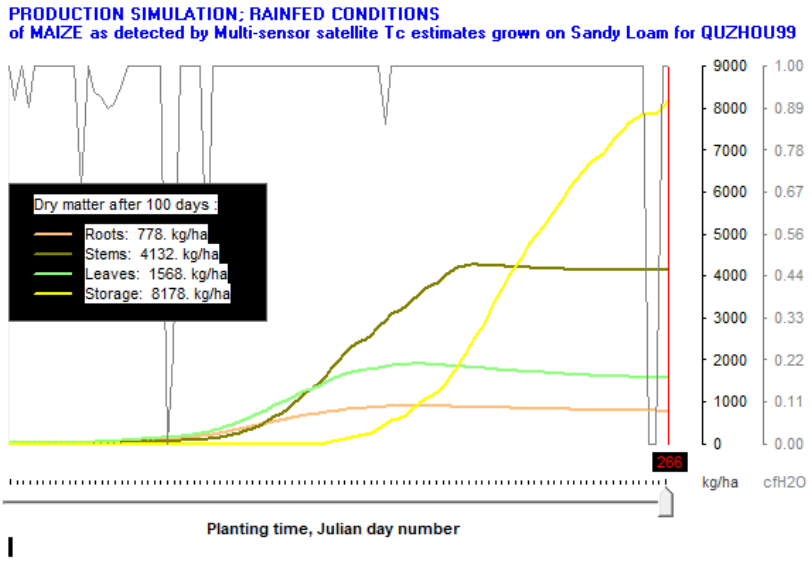

Figure 6. Maize yield at Quzhou research station using NOAA/AVHRR satellite

Grain yield of maize at Quzhou research station was 8278 kg ha^{-1} using Polar and geostationary satellites in combination (Figure 7).

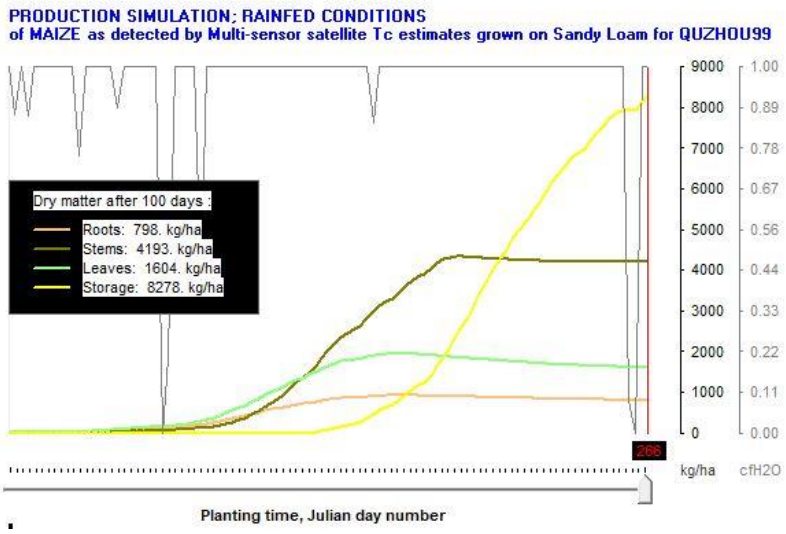

Figure 7. Maize yield at Quzhou research station using GMS-5 satellite

Q. Is the error in your estimate acceptable?

When evaluated against SOM values as observed (8453 kg ha^{-1}) at the experimental maize fields, the estimates are within an accuracy of about 175 kg ha^{-1}, a relative error of less than 2.08%.

Observed yield (SOM values) = 8453 kg/ha

Difference = 8453-8278 = 175 kg/ha

Error= 2.07 %

The error value is higher than threshold value of 1.8%. So, this estimation may be rejected.

Q. How different are the drought stress periods between NOAA/AVHRR alone ("N14-99Tc.dat") and the two far-thermal satellite platforms combined ("N14+GMS5-99Tc.dat")?

There were total 8 times drought were observed in the maize growing period (field duration 100 days). According to the PSn simulation model, when two far-thermal satellite platforms were combined the first stress period lasts for two days (Julian day: 182 – 184), whereas NOAA/AVHRR alone showed six days drought stress periods (Julian day: 178 –184).

Q. Is a satellite pixel representative, and is a daily snapshot sufficient to capture the thermodynamics of a field crop do you think?

To be representative a satellite pixel must cover the area of interest with desired pixel size as well as cloud-free. Besides, at field level thermodynamics is determined by micro-climatic variation. So, periodic image data of the same pixel could be useful for monitoring.

A daily snapshot would be sufficient to capture the thermodynamics of a field crop if we incorporate additional weather and canopy parameters with the thermal image. Addition of hourly weather phenomenon like air temperature, dew point temperature, wind speed, solar radiation etc. and canopy emissivity, leaf area index etc. could improve the model accuracy.

Reference

Venus, V., & Rugege, D. (2004). Combined use of polar orbiting and geo - stationary satellites to improve time interpolation in dynamic crop models for food security assessment. In *ISPRS 2004 : proceedings of the XXth ISPRS congress : Geo-imagery bridging continents, 12-23 July 2004, Istanbul, Turkey. Comm. VII PS, WG VII/2. pp. 212-219* (pp. 212-219). International Society for Photogrammetry and Remote Sensing (ISPRS). http://www.itc.nl/library/Papers_2004/peer_conf/venus.pdf