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Application of Thermal Remote Sensing in Study on Surface Temperature Distribution of Ho Chi Minh City

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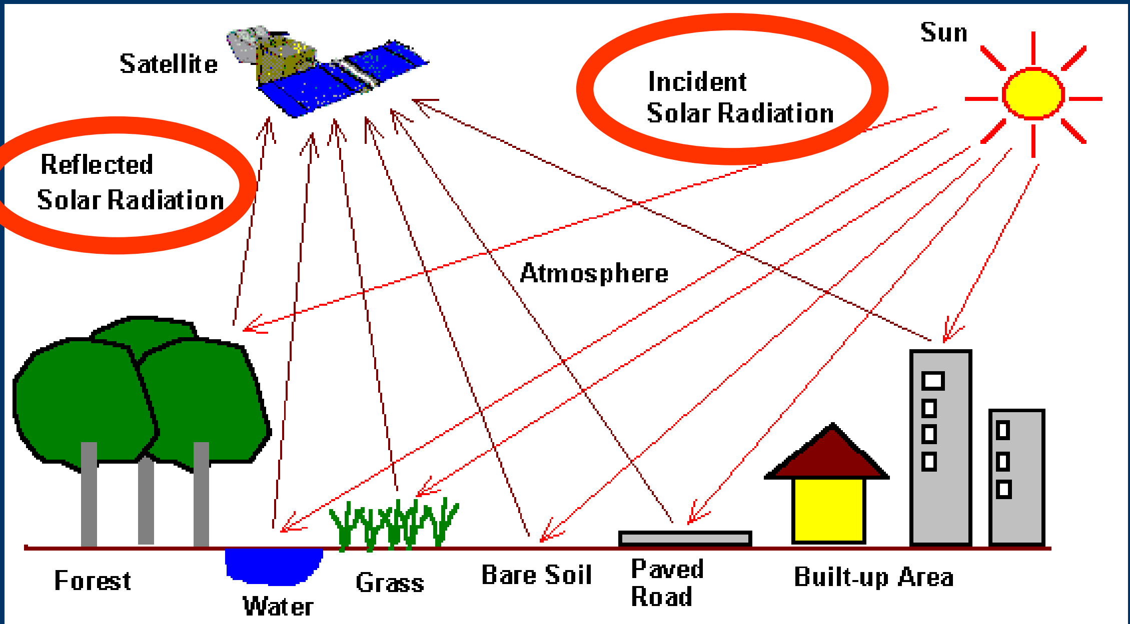
INTRODUCTION

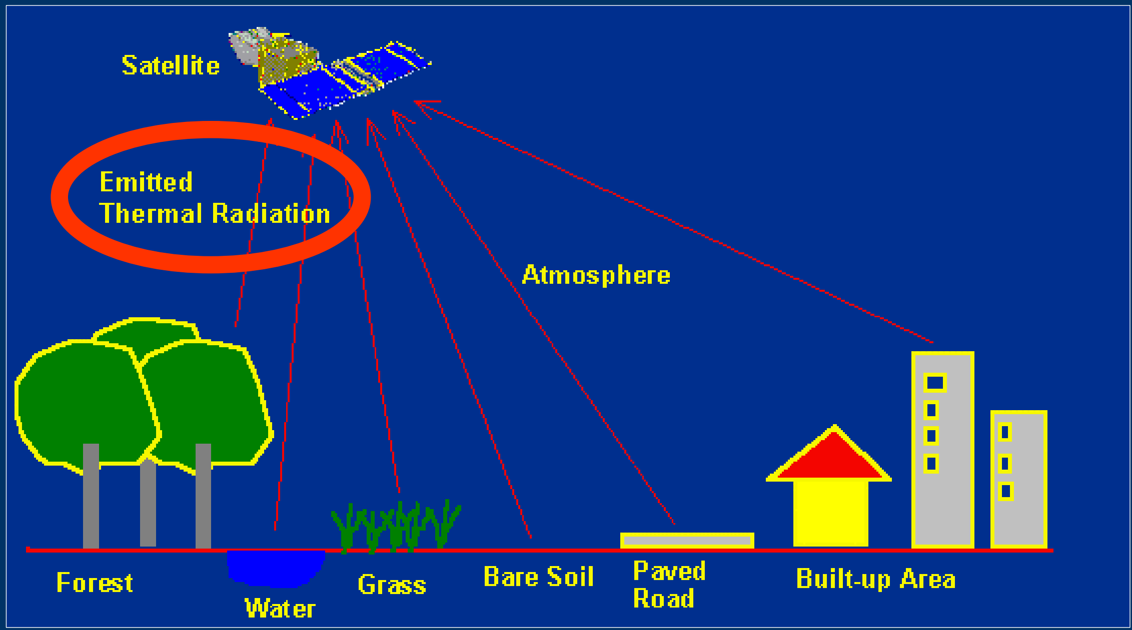
- Land surface temperature (LST) → important variable used in lots of applications, particularly in climate change studies
- In urban areas, natural land cover is replaced by impervious surfaces lacking evaporation capacity → change the LST
- LST from satellite images provides a panorama of the Earth’s surface or a region → potential of thermal remote sensing

OBJECTIVES

- Study of method to determine LST in urban level corrected by land surface emissivity (LSE).
- The study results were verified with the in-situ observed LST measures for accuracy assessment
- Apply for building distribution map of LST on Ho Chi Minh City to detect the surface heat island (SHI)

BACKGROUND


Satellite
Sun
Incident
Solar Radiation
Reflected
Solar Radiation
Atmosphere
Forest
Water
Grass
Bare Soil
Paved
Road
Built-up Area

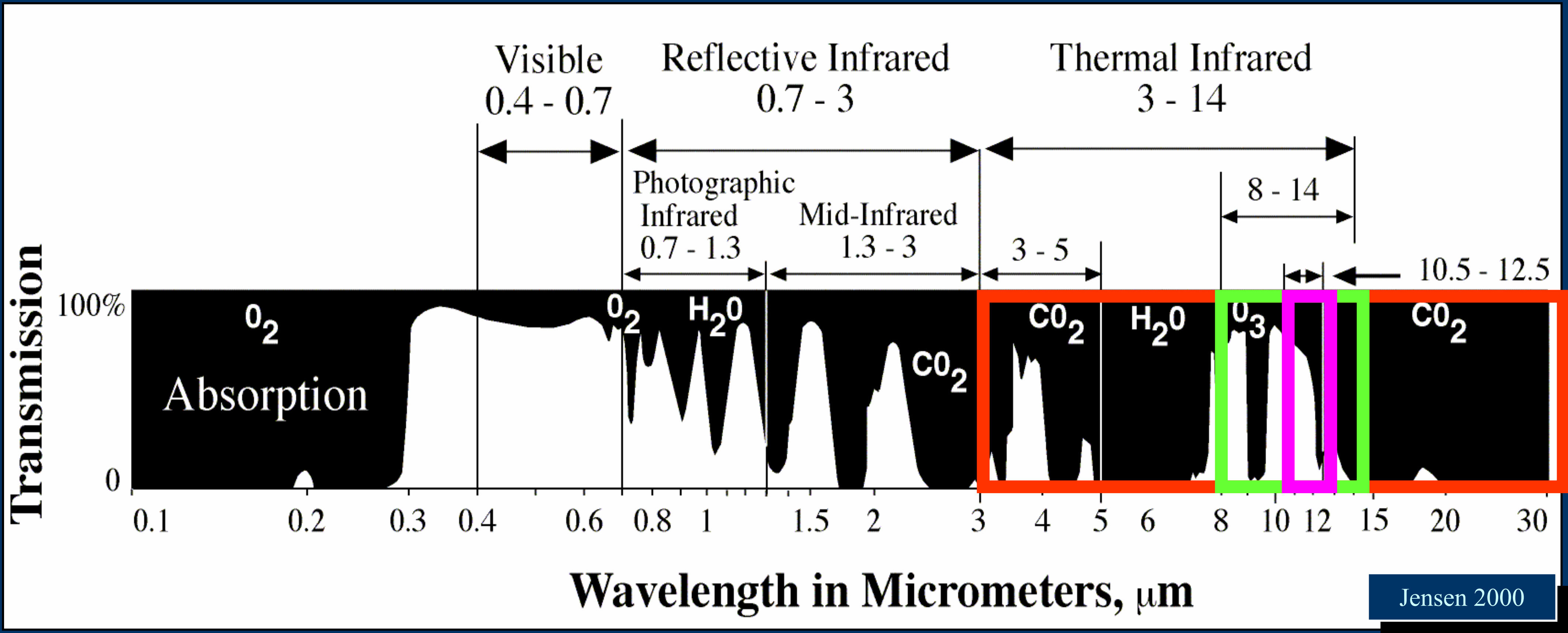

Satellite
Emitted
Thermal Radiation
Atmosphere
Forest
Water
Grass
Bare Soil
Paved
Road
Built-up Area

Earth radiant energy = f (temperature, emissivity)

Temperature : ground surface kinetic temperature depends on heat energy budget and thermal properties of materials

Emissivity (ε) : property of materials controlling the radiant energy flux. $\varepsilon_{real\ object} < 1$, depends on color, roughness and surface state of object

Atmospheric Windows in the Electromagnetic Spectrum



Atmospheric windows: Regions that pass energy
Absorption bands: Regions that absorb most of the infrared energy

Remote sensing devices detect infrared energy in these regions because the atmosphere allows a portion of the infrared energy to be transmitted from the terrain to the detectors.

METHOD

LST and LSE retrieval

2 problems

Atmospheric influence

Undetermination:
N channels → N+1 variables

radiance transfer model

requires complimentation assumptions for estimating LST and LSE

Review estimation methods

LST

- ❖ Single-channel method
- ❖ Split-Window Technique (SWT)
- ❖ Multi-angle method

LSE

Initially assume:
- constant emissivity (NEM, NOR)

or

- constant temperature (spectral-ratio method)

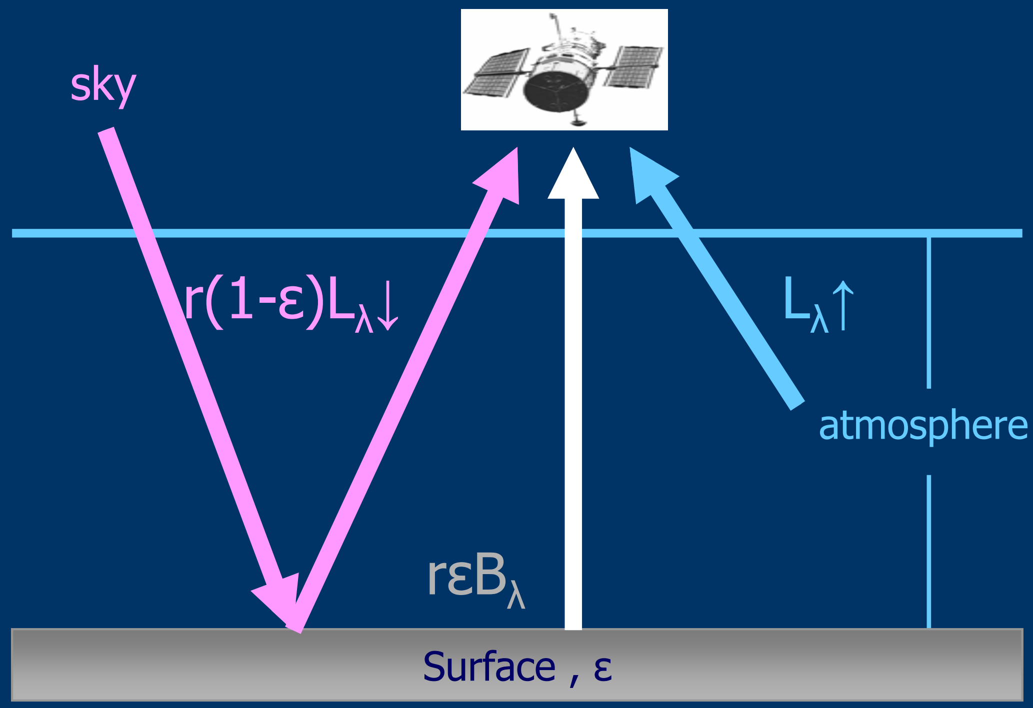
Unknown variables calculated and assumed constant ones recalculated then

- require a priori surface-information from reflective value (NDVI)

- dependent on spectral infrared channels (TES requires 4-5 TIR channels)

RADIATIVE TRANSFER: the radiance values received in the thermal region of the electromagnetic spectrum at a sensor are classified into 3 categories:

- Surface emission
- Atmospherically emitted downwelled radiance
- Atmospheric emission



$$L_{sensor,\,\lambda} = r\,\big[\underbrace{\varepsilon B_\lambda + (1-\varepsilon)\,L_\lambda\!\downarrow}\big] + L_\lambda\!\uparrow$$

Radiance from a real surface: $R_\lambda = \varepsilon\, B_\lambda$

LST ESTIMATION

Stefan-Bolzman Law for natural object:

$$B = \varepsilon \sigma T_K^{\;4} = \sigma T_R^{\;4}$$

$$T_R = \varepsilon^{1/4} T_K$$

$$T_K = \frac{T_R}{\varepsilon^{1/4}}$$

$T_R < T_K$ by $\varepsilon^{1/4}$

Planck equation for blackbody radiance

$$B_\lambda = \frac{2\pi hc^2}{\lambda^5 \left(e^{\frac{hc}{k\lambda T}} - 1\right)}$$

→ radiance temperature $T_R = T_B$ (brightness temperature)

$$T_B = \frac{K_2}{\ln\left(\frac{K_1}{B_\lambda} + 1\right)}$$

→ kinetic temperature $T_K = T_S$ (surface temperature of natural object)

$$T_S = \frac{T_B}{\varepsilon^{1/4}}$$

→ ε ???

LSE ESTIMATION

Greybody in nature (ε)

Emissivity (ε) : the ratio between the radiant flux exiting a real-world selective radiating body (R_λ) and a blackbody at the same temperature (B_λ)

$$\varepsilon = \frac{R_\lambda}{B_\lambda}$$

Or by the relationship between radiance temperature T_R and T_K kinetic temperarure

$$\varepsilon = \left(\frac{T_R}{T_K}\right)^4$$

no optimal method for estimation ε → suistable approaches in dependent on real study

Idea: This study found

- simple calculation procedure
- the calculation independent on the number of thermal bands and
- improve the spatial resolution of the final result maps.

Combined-NDVI method

NDVI METHOD for estimation ε

Mixed pixel in earth surface due to remote image resolution

→ Effective emissivity of a pixel by Valor và Caselles (1996) :

$$\varepsilon = \varepsilon_o + d\varepsilon$$

$$\varepsilon_o = \varepsilon_v P_v + \varepsilon_s (1 - P_v)$$

$$\Rightarrow \quad \boxed{\varepsilon = \varepsilon_v P_v + \varepsilon_s (1 - P_v)}$$

ε_v và ε_s : emissivities of pure vegetation and bare soil

P_v : vegetation cover fraction

NDVI

Van de Griend and Owe (1993) : $\boxed{\varepsilon = a + b.\ln(NDVI)}$

→ expirimental relationship for homogenious surfaces with a=1.0094, b=0.047

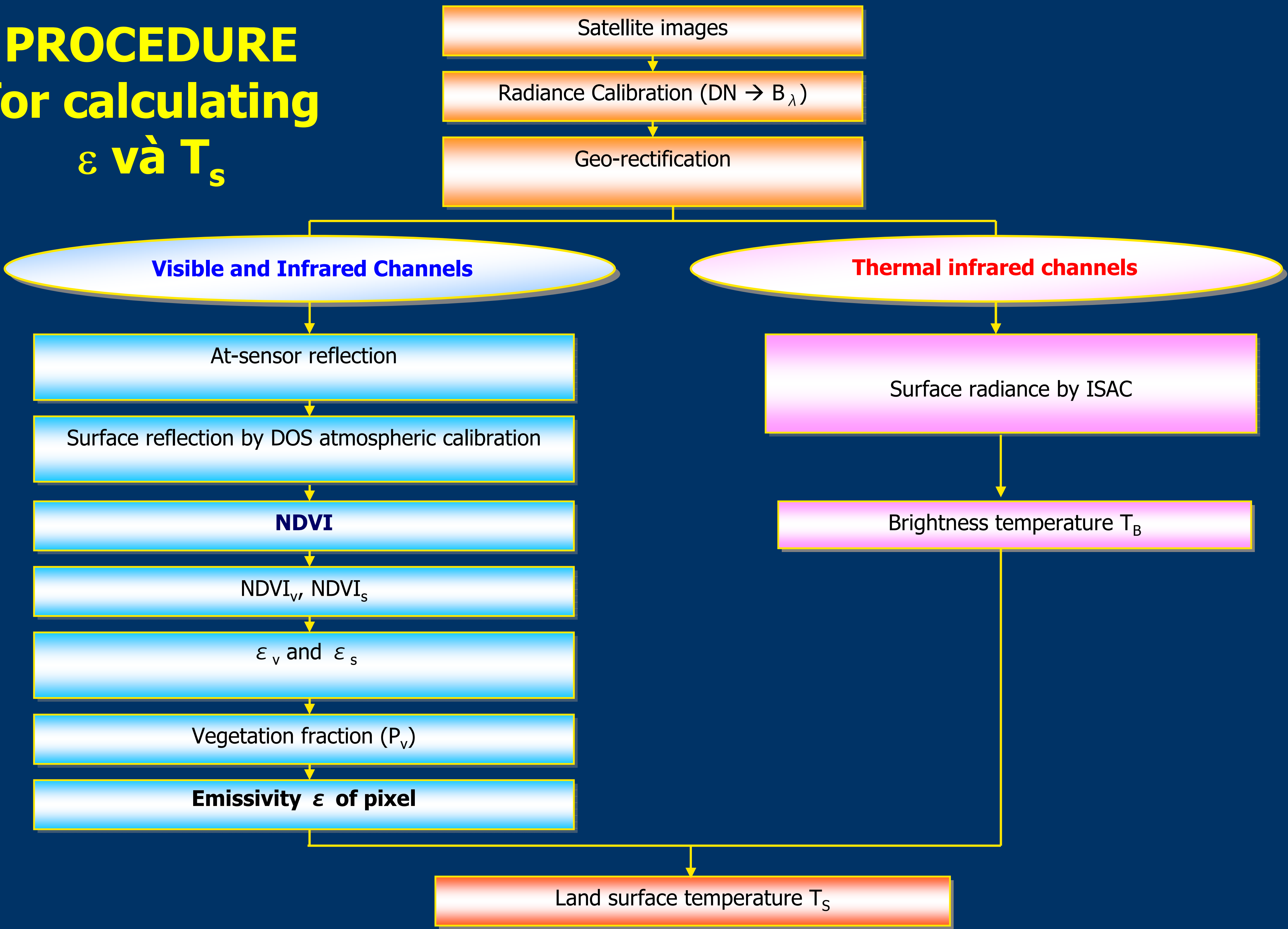
From this equation → determinated ε_v và ε_s

Gillies et al., 1997 defined P_v :

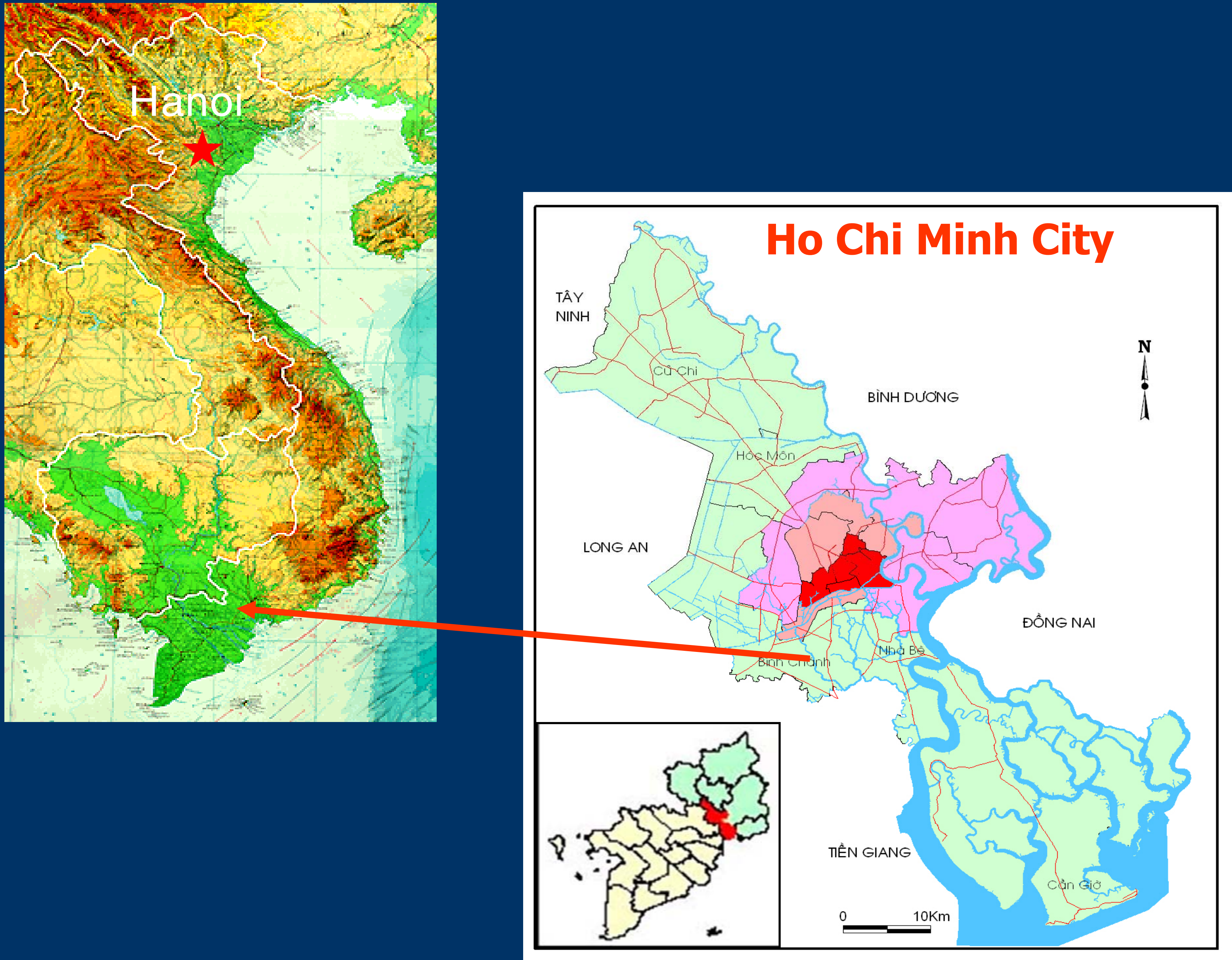
$$P_v = \left(\frac{NDVI - NDVI_s}{NDVI_v - NDVI_s} \right)^2$$

$NDVI_s$, $NDVI_v$: vegetation indices of bare soil and full vegatation

PROCEDURE for calculating ε và T_s



STUDY AREA



Hanoi
Ho Chi Minh City
TÂY NINH
Củ Chi
BÌNH DƯƠNG
Hóc Môn
LONG AN
ĐỒNG NAI
Nhà Bè
TIỀN GIANG
Cần Giờ
N
0
10Km

MATERIALS

Characterics of LANDSAT và ASTER sensors

BAND	Spectral Range (μm)	Ground Resolution (m)
Landsat ETM+ (8)		
Panchromatic	0.52 - 0.90	15
Visible & Near Infrared	0.45 – 2.35	30
TIR	10.40 - 12.50	60
ASTER (14)		
VNIR	0.4 – 1.2	15
SWIR	1.6 – 2.4	30
TIR	8.925 - 11.65	90

Used Satelite images

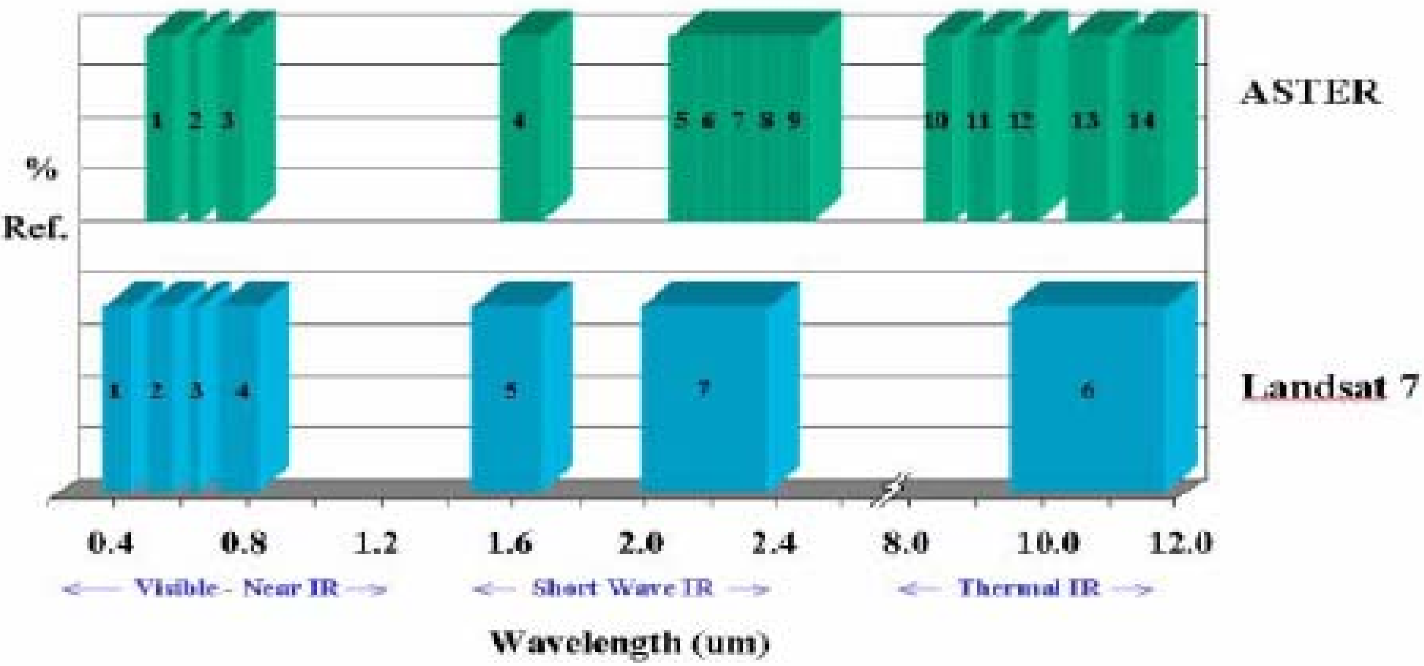


Figure 2: Comparison of Spectral Bands between ASTER and Landsat-7 Thematic Mapper.

ASTER user's guide

Sensor	Acquisition date	Processing level
LANDSAT ETM+	13-02-2002	1G
ASTER	25-12-2006	1B

EXPERIMENT

Pre-processing → surface radiance and reflection

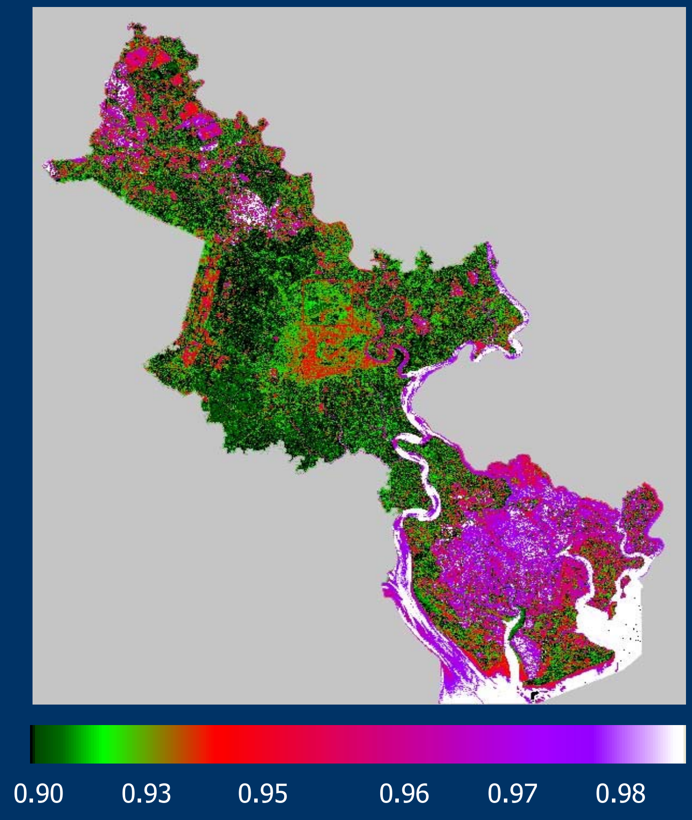
Estimating NDVI : histogram, statistics and image survey → defining $NDVI_S$ và $NDVI_V$

Defined ε_s và ε_v

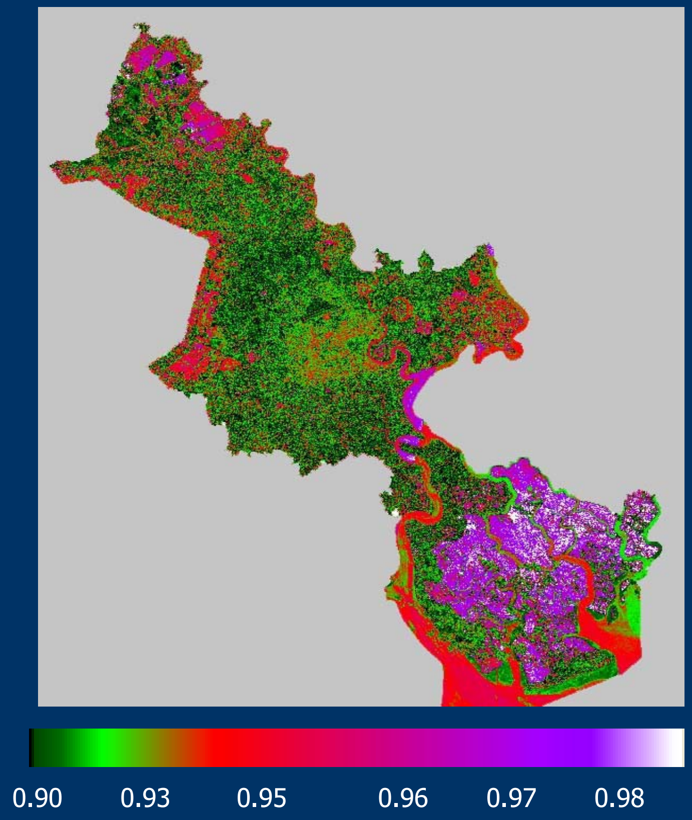
Sensor	$NDVI_s$	$NDVI_v$	ε_s	ε_v
LANDSAT	0.107	0.676	0.904	0.991
ASTER	0.106	0.725	0.904	0.994

EXPERIMENT

EMISSIVITY DISTRIBUTION



LANDSAT 2002



ASTER 2006

Land cover	ε LANDSAT	ε ASTER
Vegetation	0.92 - 1	0.92 - 1
Bare soil, urban	0.90-0.91	0.90 – 0.91
Water	0.92 – 0.95	0.91 – 0.92

EXPERIMENT

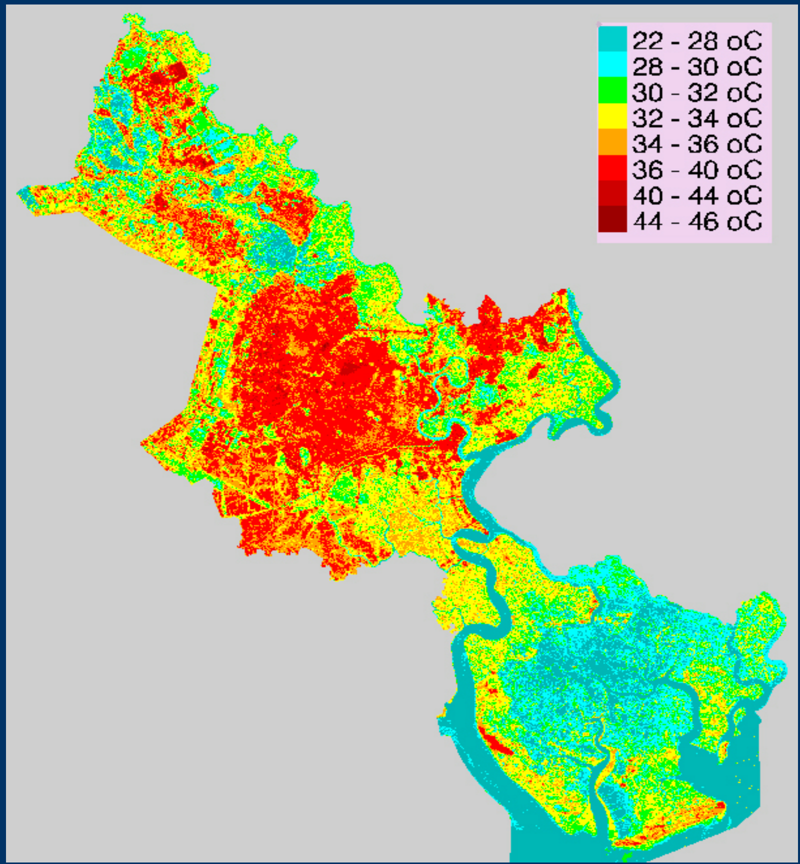
ESTIMATION LST

LANDSAT : band 6 (10.40 - 12.50 μm)

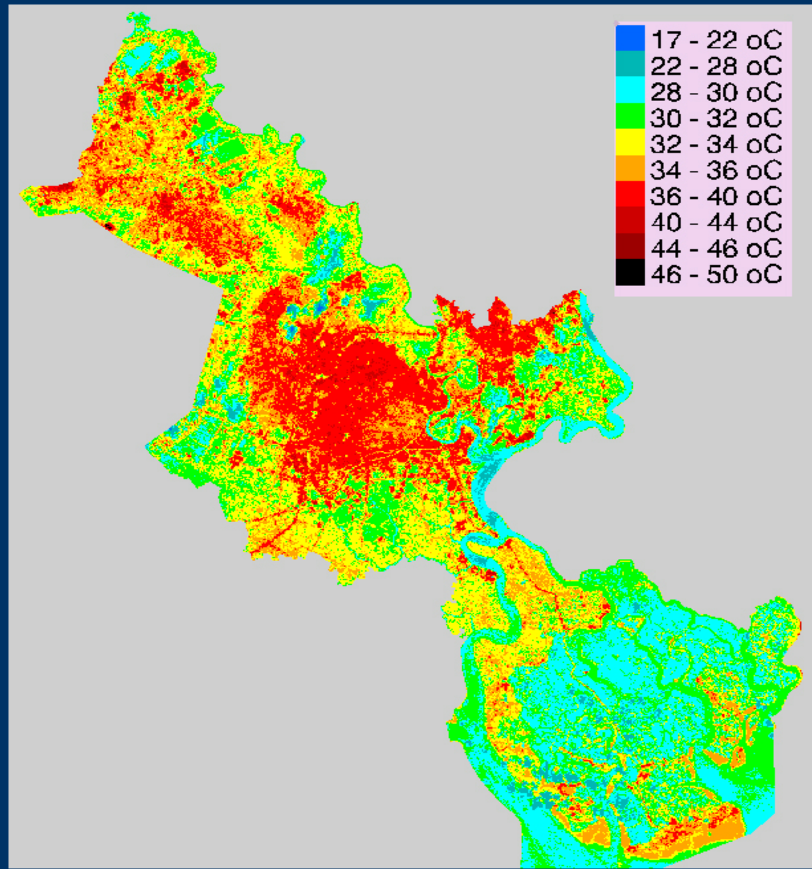
ASTER : 5 bands from 10 – 14 (8.925 - 11.65 μm)

calculating LSt from each band giving different LSTs → T max in wavelength range 10 - 12μm → T wil be calculated from bands 13 và 14, max value from these wil be the results

EXPERIMENT LST DISTRIBUTION



LANDSAT 2002



ASTER 2006

SHI - High LSTs – were found in built-up, industrial regions in compared with regions covered vegetation and water

Sensor	Min (°C)	Max (°C)
LANDSAT ETM+	23.2	45.9
ASTER	17.4	49.4

EXPERIMENT LST DISTRIBUTION

Distribution of LST and land cover has spatial relationship by the thermal properties of the surface objects

LST product derived from the thermal remote sensing data will be useful for detecting land cover as well as for evaluating change detection in researching urbanization through the impervious surfaces

ACCURACY ASSESSMENT

Compare satellite image-based estimated T_S with:

1. Measured values from 10 experimental observated points
2. Calculated T_B (uncounted ε)
3. Calculated T_S from NOR method
4. Calculated TS from method of Artis và Carnahan (called AC in this presentation)
5. T_S from AST08 product of TES method especially for Aster images

$$\text{bias} = \frac{1}{N}\sum_{i=1}^{N}\left(T_{Si}^{\text{tính}} - T_{Si}^{\text{đo}}\right)$$

$$E(\%) = \frac{\left|T_{Si}^{\text{tính}} - T_{Si}^{\text{đo}}\right|}{T_{Si}^{\text{đo}}} * 100$$

ACCURACY ASSESSMENT

Results estimation T_S from different methods

Method	Bias (°C)	E(%)
TES – AST08	**0.81**	**2.24**
Combined-NDVI	**1.95**	**5.42**
AC	2.01	5.59
NOR	6.83	19.0
Uncounted ε (T_B)	7.24	20.14

LST from TES method

. the lowest error

. but LST image resolution 90mx90m

→ method for only Aster TIR images and require complex atmospheric correction

LST from NDVI method

. higher LST image resolution 15mx15m (Aster image) or 30mx30m (Landsat image)

→ method not dependent in number of TIR bands

CONCLUSION

- ❖ LST measurements from the meteorological stations → higher temporal resolution, but are recorded at only a few sites from sparse stations → cannot tell us the temperature for all required locations
- ❖ Thermal RS → potential for estimating LST → the picture of LST distribution in a whole area
- ❖ Thermal RS for studying the LST distribution in HCMC → the LST gradient pulled from the central urban areas to the rural one related to the land cover, formed the surface heat islands on the city
- ❖ NDVI method for estimating the emissivity-corrected LST : optimal method, results have shown that the bias of estimated value compared with the field in-situ measured one less than 2^{o}C:
  - ❖ simple calculation procedure,
  - ❖ independent on the number of thermal bands and
  - ❖ improve the spatial resolution of the final result maps.


Thank you for attention