Split Window

Initial Approach

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Section 7.3.2.3 Multiple-Bandpass Technique

In the multichannel approach, the basic radiative transfer equation is expressed as:

$$L(h,\theta) = L(0,\theta)\tau(h,\theta) + L_{TA}[1-\tau(h,\theta)]$$

Equation 7.30

Recall that for atmospheres dominated by absorption effects, the transmission can be expressed as:

$$\tau(h,\theta) = e^{-C_{\text{ext}}mz}$$

Equation 7.31

this can be expanded using a Taylor series and truncated to yield as a good approximation:

$$\tau(h,\theta) \approx 1 - C_{\text{ext}}mz$$

Equation 7.32

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then Eq. (7.30) becomes

$$L(h,\theta) = L(0,\theta) - [L(0,\theta) - L_{TA}]C_{\text{ext}}mz$$ Equation 7.33

Expanding the Planck radiance equation about temperature and keeping only linear terms yields

$$T_i(h,\theta) \cong T(0) - [T(0) - T_A]C_{\text{ext}i}mz$$ Equation 7.34

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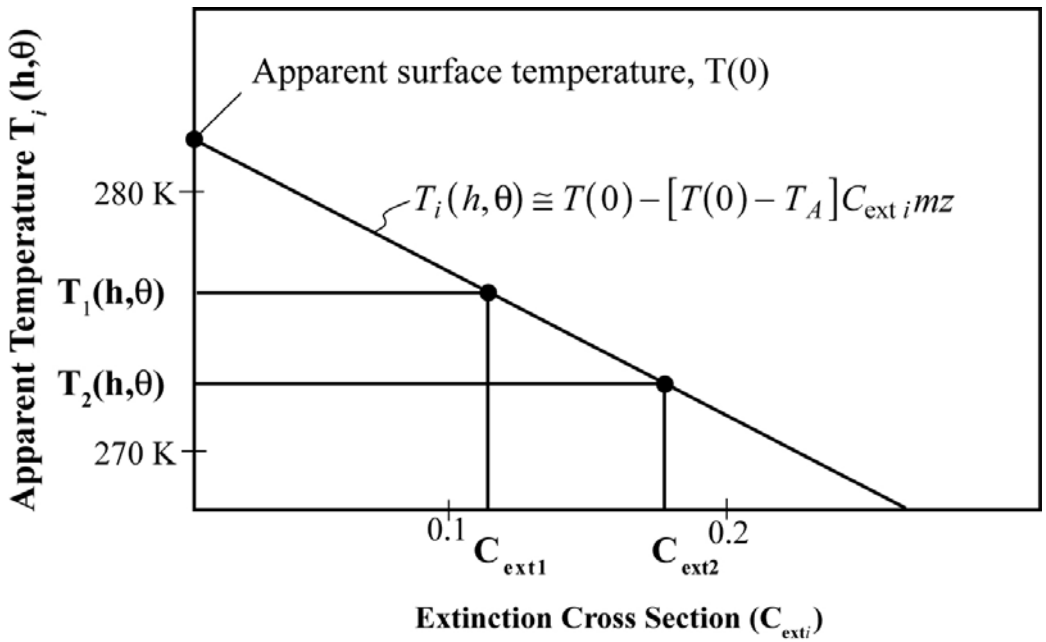


Figure 7.5

The multiple look angle calibration technique assumes vertical layering of a horizontally homogeneous atmosphere.

For any given atmosphere, the effective observed spectral radiance can be expressed as:

$$L_{\lambda \mathrm{eff}} = \frac{\int \left[\varepsilon L_{T\lambda} \tau + r L_{d\lambda} + L_u \right] \beta(\lambda) d\lambda}{\int \beta(\lambda) d\lambda} \qquad \text{Equation A}$$

The temperature radiance relationship can be found using the Plank function:

$$L_{T\,\mathrm{eff}} = \frac{\int L_{\mathrm{plank}\ T\ \lambda} \beta(\lambda) d\lambda}{\int \beta(\lambda) d\lambda} \qquad \text{Equation B}$$

where β is the spectral response,

If $\varepsilon = 1$, we can vary T and run MODTRAN to generate $L_{\lambda\,\mathrm{eff}}$ values i.e.,

$$L_{\lambda\,\mathrm{eff}} = \tau_{eff} L_{\mathrm{T\,eff}} + L_{\mathrm{u\,eff}}$$

This has the form $y = mx + b$

yielding

$$\tau_{\mathrm{eff}} = \mathrm{m} \quad L_{\mathrm{u\,eff}} = \mathrm{b}$$

If we then look at fixed $\varepsilon = 0.9$ and vary T

$$L_\lambda = \varepsilon\, L_{\mathrm{T\,eff}}\,\tau + (1 - \varepsilon)\, L_d \tau + L_{\mathrm{u\,eff}}$$

$$L_\lambda = m\, L_{\mathrm{T\,eff}} + b$$

$$b = (1 - \varepsilon)\, L_d \tau + L_{\mathrm{u\,eff}}$$

$$L_{\mathrm{d\,eff}} = \frac{b - L_{\mathrm{u\,eff}}}{\tau(1 - \varepsilon)}$$

to yield effective downwelled for each band.

Given effective values a radiance to temperature LUT created by using Equation B can be used to compute

$$T_{Ai} \text{ from } L_{ui}$$

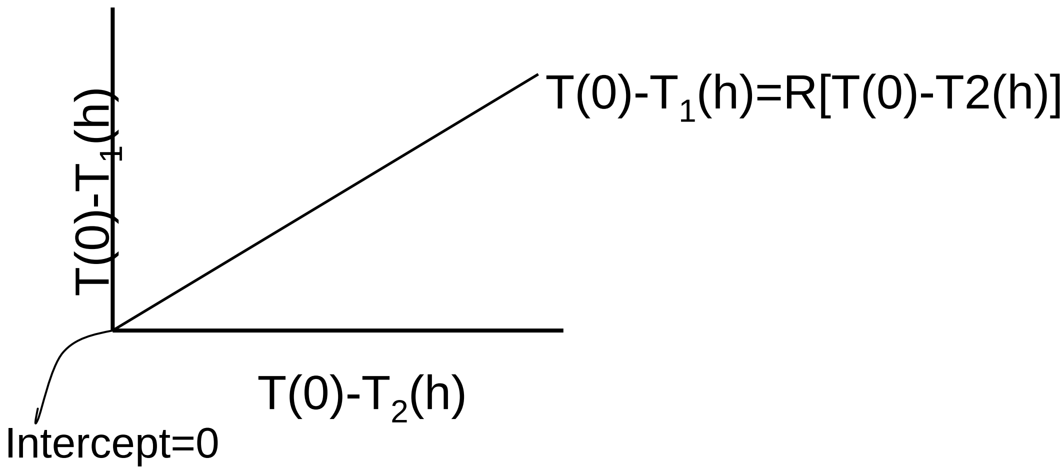
$$\delta_i = C_{ext}\, mz \text{ from } -(\ln(\tau_i))$$

$$T_i(0) \text{ from } \varepsilon_i L_{T_i\,eff} + (1 - \varepsilon_i) L_{d_i}$$

Note for $\varepsilon = 1$, this is just $L_{T\,eff}$ from Equation B converted through LUT, and $T_1(h)$ and $T_2(h)$ for each target temperature i.e., Equation A converted to temperature through LUT i.e., in practice this is just MODTRAN sensor reaching spectral radiance converted to apparent temperature.

Start by solving for $T(0) - T_1(h)$ and $T(0) - T_2(h)$

For a range of surface temperatures, $\varepsilon = 0$, and a range of temperate atmospheres. Then plot



Solve for R by linear regression and linear regression with zero intercept

Test

$$\hat{T}(0) = \frac{T_1(h) - R\, T_2(h)}{1 - R} \qquad \text{Equation C}$$

For test data set and compute error

$$\varepsilon = \hat{T}(0) - T(0)$$

Solve for RMS error

Then with no knowledge of in algorithm test results on gray bodies i.e., solve Equation C based on MODTRAN values for L_1 and L_2 with varying T and emissivity to yield

$\hat{T}(0)$ and $T(0)$ and from Equation B for the target T.

Later on we may want to try to do better if we guess ε .

Repeat for a wider range of atmospheres.

We may want to estimate $C_{\text{ext i}}$ using Equation 7.34

$$T_i(h,\theta) \cong T(0) - [T(0) - T_A] C_{\text{ext}i} mz$$

for many runs of each type of atmosphere.

T_A is just result of LUT to convert L_u to T_A .
Even a crude estimate of $C_{\text{ext i}}$ would let us estimate T_A from individual atmosphere according to

$$T_i(h) = T(0) - (T(0) - T_A)\, C_{ext\ i}$$

$$y = b + m\,(x)$$

$$m = -(T(0) - T_A)$$

$$b = T(0)$$

OR $\hat{T}_A = m + b$

Given $\hat{T}_A$ we could decide what flavor of atmosphere type we had and change R i.e., we would have R for dry, medium and wet atmospheres or dry-cold, dry-hot, medium-hot, medium-cold, etc.

When only two spectral bands are used, the apparent surface temperature can be expressed in terms of the ratio of the extinction cross sections between the bands

$$T(0) = \frac{T_1(h,\theta) - RT_2(h,\theta)}{1-R} \qquad \text{Equation 7.35}$$

$R = C_{ext1}/C_{ext2}$

Initial Calibration Parameters

- Initial calibration parameters will be created using temperate radiosonde data
  - Create MODTRAN runs from radiosonde data, utilizing proposed specifications of TIRS imager
    - Simulated radiosonde may be used without affecting the validity of the method
  - Modify parameters within MODTRAN to generate all necessary data
  - Develop initial calibration equation using split-window analysis
- This equation will be tested for robustness with global radiosonde (including tropical and arctic atmospheres), as well as night radiosonde.

MODTRAN Parameters

- Run each radiosonde file in MODTRAN several times, modifying:
  - Surface Temperature: 265 K – 311 K (3K)
  - Emissivity: 1.000, 0.986, 0.950, 0.900
  - The following modifications can be accomplished in one of two ways: tweak the parameters within MODTRAN, or gather more radiosonde from the same location
    - Water Vapor: +/- 10%, 25%, 50%
    - Visibility/Aerosols: +/- 10%, 25%, 50%
    - Ozone: +/- 10%, 25%, 50%

Output

Comment	Tropical Model 1
Day of Year	140
Location/Lat-Long	43.125/77.625
Time	15.4
Ozone	model
Temperature	268
Emissivity	0.986
Atmosphere: Water	-
Atmosphere: Visibility	-
Atmosphere: Ozone	-
Radiance (9µm) … (13.5µm)	…
Average Transmission	0.4701
Transmission (9µm) … (13.5µm)	…
Upwelled Radiance (9µm) … (13.5µm)	…
Downwelled Radiance (9µm) … (13.5µm)	…