DEFENCE DÉFENSE

Temperature and emissivity separation

Pierre Lahaie

STEM held at DRDC Valcartier

April 7 2009

Defence Research and Development Canada · Recherche et développement pour la défense Canada

Canada

Plan

- Introduction
- The DEFILTE algorithm
- A simple atmospheric compensation algorithm
- The NEM algorithm for TES
- Application to Camp Dubé data (Blackfly)
- Application to Nicolet data (Blackfly)
- Conclusion

Introduction

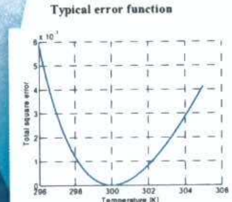
- Camp Dubé was the main site in the Blackfly trial
  - Calibration site was installed
  - Ground truth was acquired
- Westfly experiment
  - Application of TES to image drom a uranium mill
  - Airborne data from 1000 m altitude

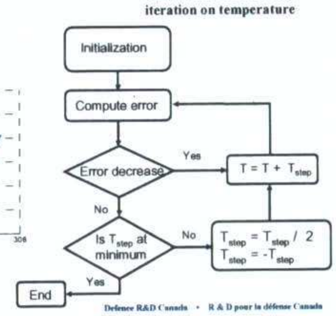
DEFILTE algorithm (structure)

DEcoupling by FILtering of Temperature and Emissivity

Minimum is found using iteration on temperature

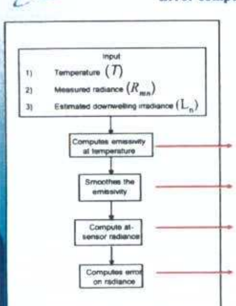
Typical error function





DEFILTE

Error computation



$$\varepsilon_n = \frac{R_{mn} - L_n}{B_n(T) - L_n}$$

$$\tilde{\varepsilon}_j = \sum_n G_{jn} \varepsilon_n$$

$$R_{ej} = \tilde{\varepsilon}_j B_j(T) + (1 - \tilde{\varepsilon}_j) L_j$$

$$E_T^2 = \sum_n (R_{mn} - R_{en})^2 \quad j \Rightarrow n$$

Variables

1) n -> band index
2) j -> band index after filtering
3) G_{jn} -> Linear filer coefficient
4) ε_n -> Computed emissivity
5) $\tilde{\varepsilon}_j$ -> Filtered emissivity
6) R_{ej} -> Radiance with error due to smoothing
7) E_T^2 -> Total squared error on radiance

Advantages of DEFILTE

- Strong against noise
- Strong against error on input parameters
- Availability of tools to estimate algorithm performance depending on operation conditions

Disadvantage of DEFILTE

- Requires the input of downwelling irradiance

Assumption under DEFILTE

- The emissivities are spectrally smooth

A simple technique for atmospheric compensation
Removal of atmospheric effects

- Path radiance and transmittance
- Assumptions for airborne data acquisition
  - Over 10 degrees Planck's law is almost linear
  - Vegetation and water have very high emissivities ~0.99
  - In some bands transmittance is very high
    - Especially true for low altitude airborne data

The pixel having the smoothest equivalent temperature is the air's most representative average temperature

The highest temperature of the warmest vegetation pixel is representative of the pixel's temperature

Defence R&D Canada • R & D pour la défense Canada

The method

- Radiance: $R = (\varepsilon B + (1-\varepsilon)L)\tau + R_p$
- Two pixels having high emissivities: Measured radiance
- Cool Pixel $R_1 \approx B_a$
- Warm Pixel $R_2 \approx B_w\tau + (1-\tau)B_a$
- Transmittance: $\tau = \dfrac{R_2 - R_1}{B_w - R_1}$
- Path radiance: $R_p = (1-\tau)R_1$

ε: Emissivity ~1
B: Blackbody function
L: Downwelling irradiance
τ: Transmittance
R_p: Path radiance ~ $(1-\tau)B_a$

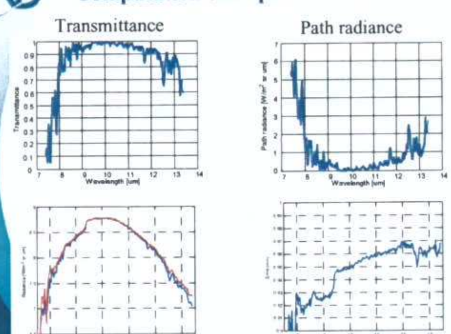
Defence R&D Canada • R & D pour la défense Canada

Pixel's selection

- Cool pixel
  - Find a pixel having a radiance close to the blackbody shape
    - Same temperature as the average atmosphereic layer
    - High emissivity
- High emissivity warm pixel
  - Use of high transmittance bands
    - Compute the standard deviation of the equivalent temperatures
      - Warm pixel
      - Smallest standard deviation
  - Estimate a temperature for the pixel (max of equivalent temperature)

Defence R&D Canada • R & D pour la défense Canada

Computation examples



The NEM algorithm for TES

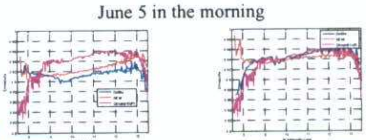
- NEM => Normalized emissivity method
  - For vegetation and water $\varepsilon \sim 0.99$
  - For minerals things can be different $\varepsilon \sim 0.96$
- Compute the equivalent temperatures
- The highest equivalent temperature => the Highest emissivity
- Recompute the emissivities from the estimated temperature

Defence R&D Canada • R & D pour la défense Canada

Application to Blackfly Data
Camp Dubé: Target SID 01

June 4 in the afternoon

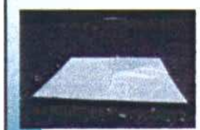
June 5 in the morning



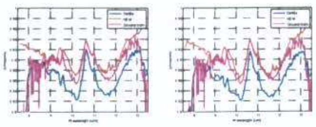
Defence R&D Canada • R & D pour la défense Canada

Application to Blackfly Data

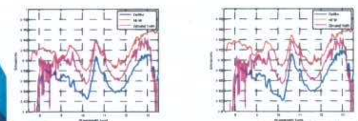
Camp Dubé: Target SID 03



June 4 in the afternoon



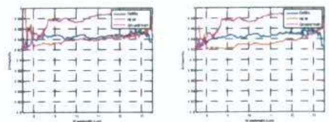
June 5 in the morning



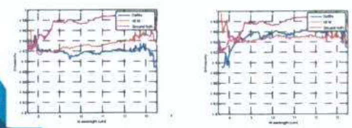
Application to Blackfly Data

Camp Dubé: Target SID 05

June 4 in the afternoon



June 5 in the morning



Application to Westfly data

Conclusion

- Two algorithms output have been shown (DEFILTE and a simple algorithm)
- DEFILTE requires the downwelling irradiance
  - Requires calibration targets
  - Difficult to retrieve from other means
- The simple algorithm makes atmospheric compensation
  - Atmospheric features remain in the emissivity
  - Applicable to acquisition where there is no calibration targets
- The results are comparable
  - No results for highly reflective targets
- What are the requirements for identification techniques
  - How clean must be the input emissivity

DEFENCE DÉFENSE