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Extraction of temperature and emissivity from airborne thermal hyperspectral imagery

Pierre Lahaie
DRDC-Valcartier
Spectral and Geospatial exploitation section
SAFF Washington
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Plan

- Introduction
- The DEFILTE algorithm
- STAC (Simple Technique for Atmospheric Correction)
- Application to Camp Dubé data (Blackfly)
- Application to Westfly data
- Conclusion

Introduction

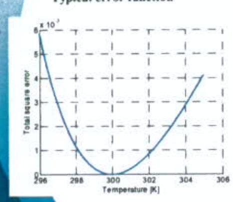
- Blackfly has been held in June 2004
  - Main site: Camp Dubé in CFB Valcartier
  - Calibration site was installed
    - Defilte and STAC are applied for comparison
  - Ground truth is available
  - Many targets of interests were deployed
- Westfly experiment has been held in August 2006
  - STAC is applied to image from a mining facility
  - Airborne data from 1000 m altitude

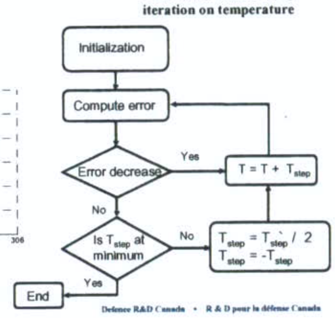
DEFILTE algorithm (structure)

DEcoupling by FILtering of Temperature and Emissivity

Minimum is found using iteration on temperature

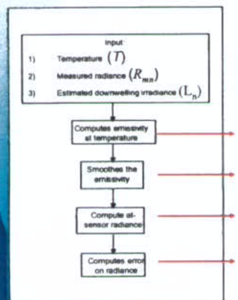
Typical error function





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 filter 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

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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: $\tau = \frac{R_2 - R_1}{B_w - R_1}$
- Path radiance: $R_p = (1-\tau)R_1$

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

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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)

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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

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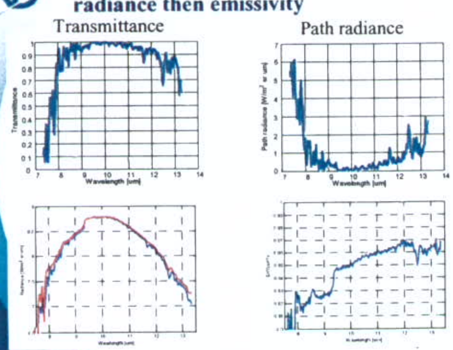
Transmittance, path radiance, measured radiance then emissivity



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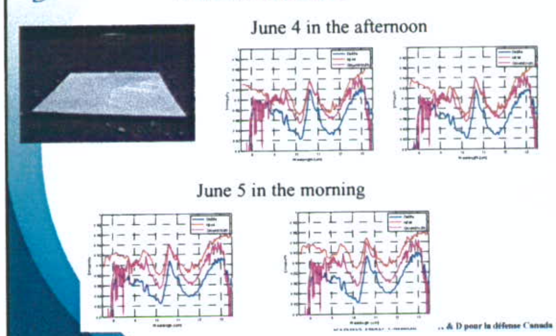
Application to Blackfly Data

Camp Dubé: Target SID 03



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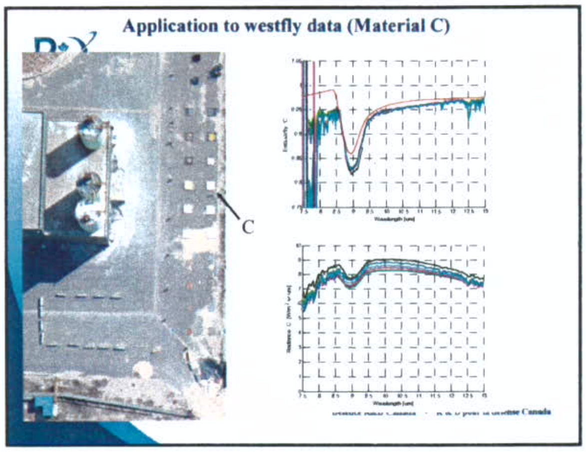

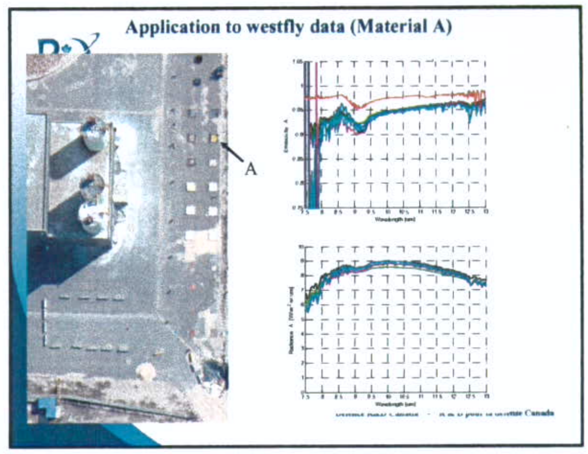

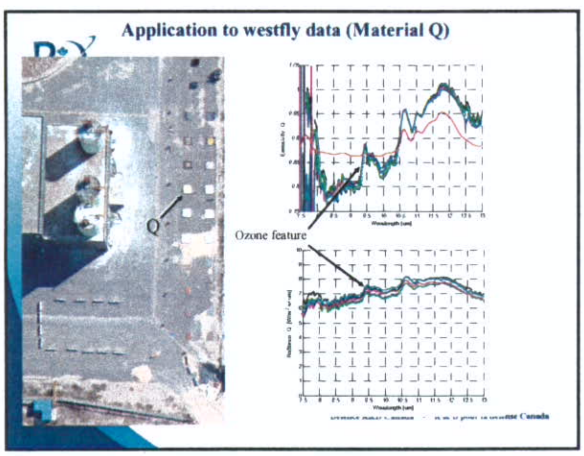

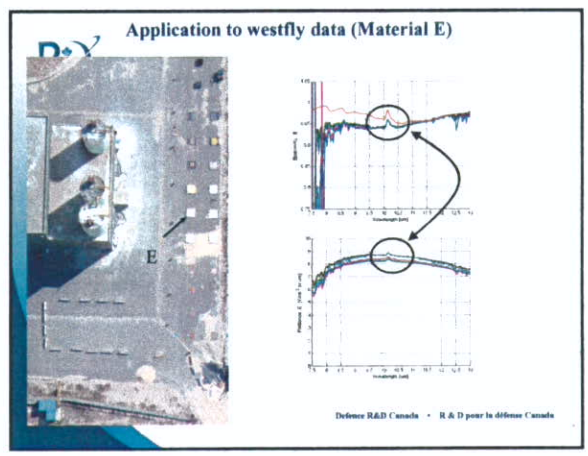

Conclusion

- Two algorithms output have been shown (DEFILTE and STAC)
- DEFILTE requires the downwelling irradiance
  - Need calibration targets
  - Difficult to retrieve from other means
- The simple algorithm makes atmospheric compensation
  - Enhancement of spectral features
    - More representative than radiance
    - Offset removal from radiance
  - Some atmospheric features (reflection) remain in the emissivity
  - Applicable to acquisition where there is no calibration targets

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