Institute of Remote Sensing and Digital Earth
Chinese Academy of Sciences

calcon
Conference on Characterization and
Radiometric Calibration for Remote Sensing

A Method Suitable for In-flight Calibration of a UAV Hyperspectral Remote Sensor

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Outline

1. Overviews
2. Purpose
3. Field Experiment
4. Method
   - Reflectance-based method
   - The improved Irradiance-based method
5. Results and analysis
6. Conclusion

1. Overview

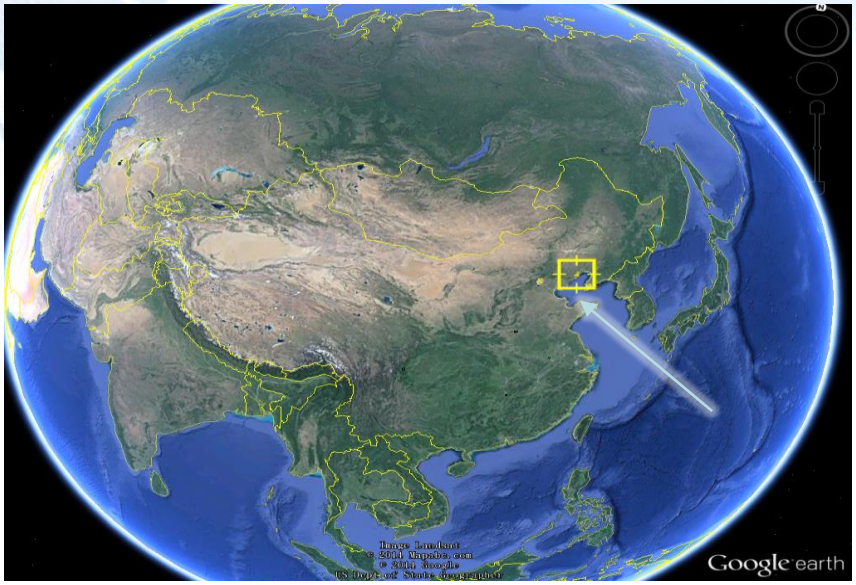
The application of UAV:

2.Purpose

The necessary of UAV's vicarious calibration unresolved question:

- To research of UAVs' quantitative remote sensing, the accuracy and precision of the measured data must be known
- The sensor aboard on the UAV is vulnerable to vibrations and natural conditions, just like erratic winds
- The vicarious calibration is closer to the real environment, and this is a supplement to the laboratory calibration.
- Most UAVs just use reflectance-based method for its vicarious calibration and with little attention to the irradiance-based method
- The error caused by aerosol types assuming is not well solved to the sensors aboard on UAVs, and this brings great systematic error

3. Field Experiment



- On the Sept 25th, 2013
- The civilian airport of Suizhong in the Chinese province of Liaoning.
  (40.23N, 120.21E)
- Runway

Long: 200m Wide:12m

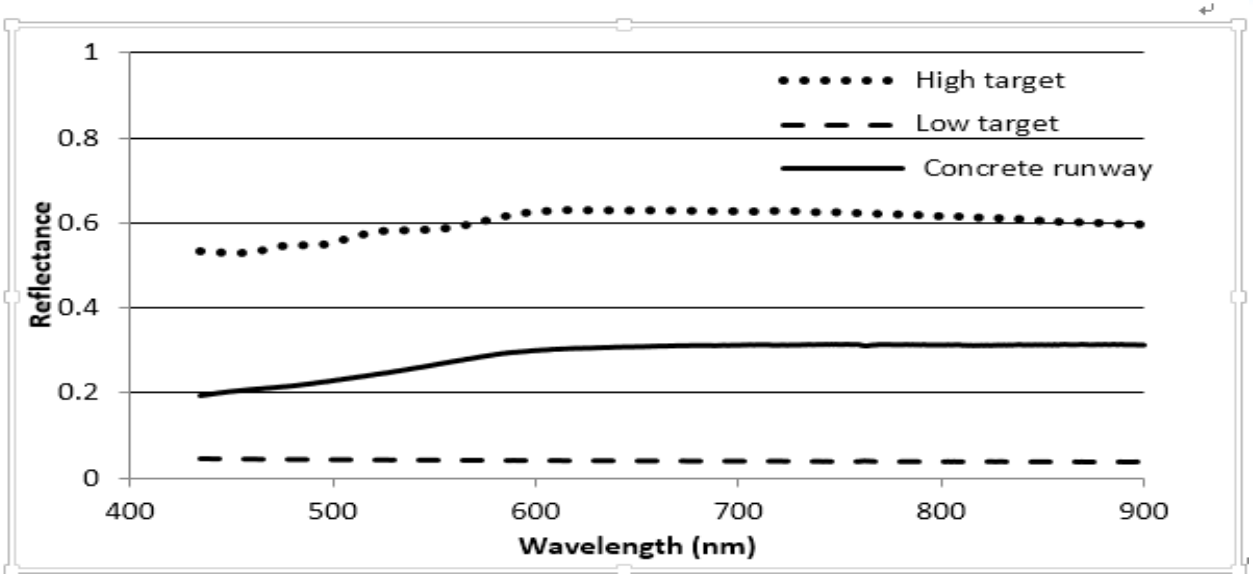
3. Field Experiment

Hyperspectral UAV(Integrated by Goldwn way Scientific, China, www.goldway.com.cn)

Headwall's Micro-Hyperspec	
Wavelength Range(nm)	380-1000nm
Spectral Resolution (nm)	<10nm
Spectral Bands	162
The most spectral line bending	0.1%
The biggest trapezoidal distortion	0.1%
Focal Length	17.0mm
Dynamic Range (db)	60dB
Weight (without lens)	0.9kg

3. Field Experiment

The measurement of ground spectrum :



Surface Reflectance

ASD

Tarp: reflectance of 60%

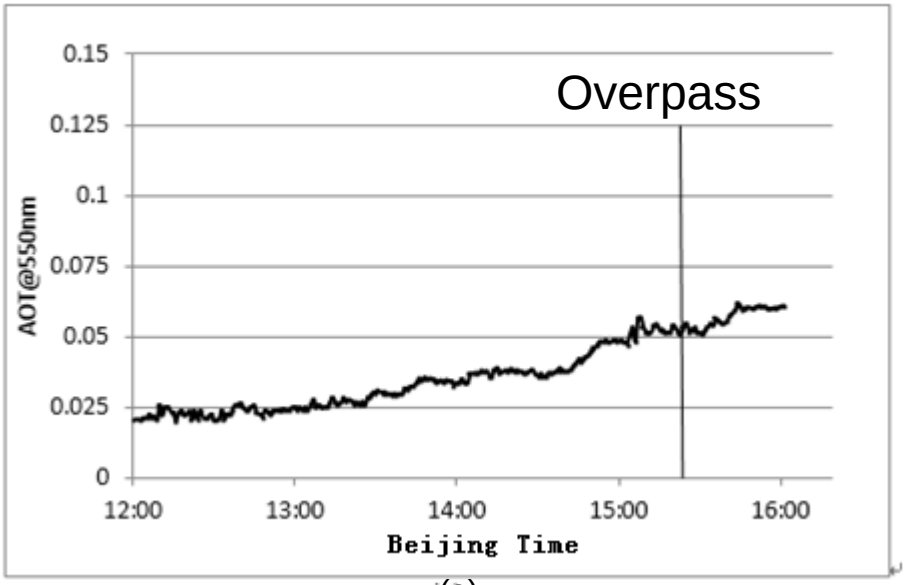
Tarp: reflectance of 5%

Cement runway

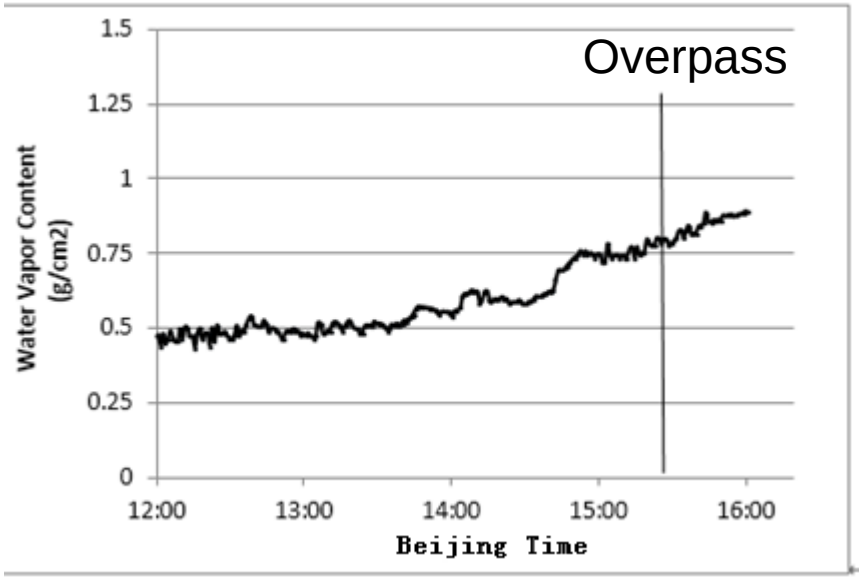
3. Field Experiment

The measurement of atmospheric characteristics :

barometer



(a)

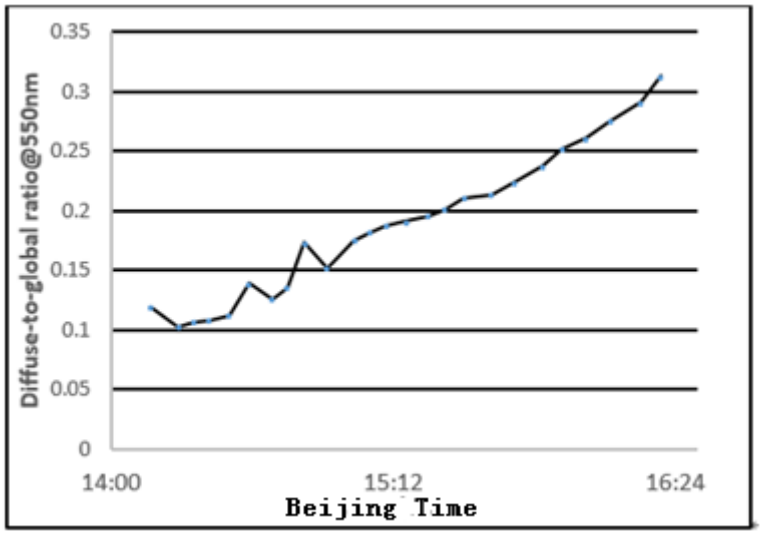


(b)

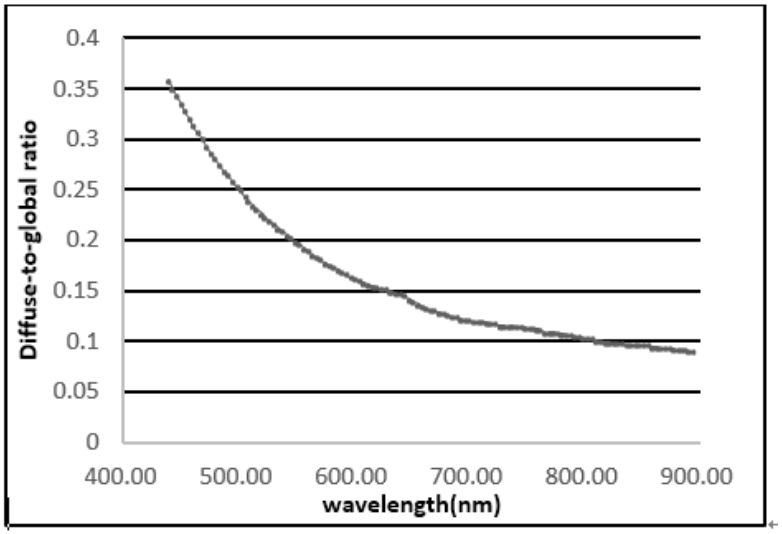
3. Field Experiment

The measurement of atmospheric characteristics :

AOD at 550 nm	0.052
Vertical column of Water Content(g/cm²)	0.776
Aerosol Type	Rural
Atmospheric Model	Midlatitude summer



(a)

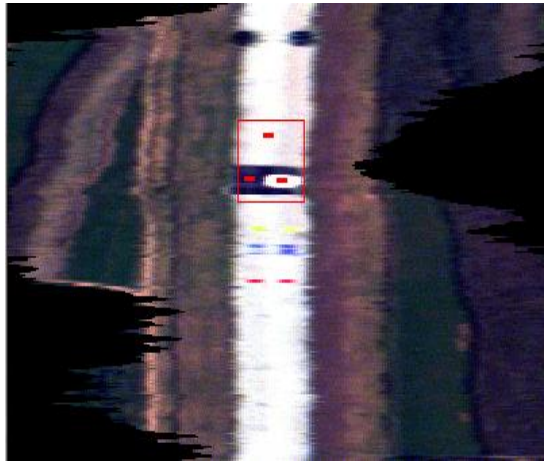


(b)

3.Method

Image Pre-Processing:

(a)



(b)

The UAV image before (a) and after (b) correction

Line-related geometric correction → POS data was used for secondary correction → The corrected UAV image

3.Method

Vicarious Calibration:

The reflectance-based method

- Less measurement data
- Widely used in sensor calibration

The irradiance-based method

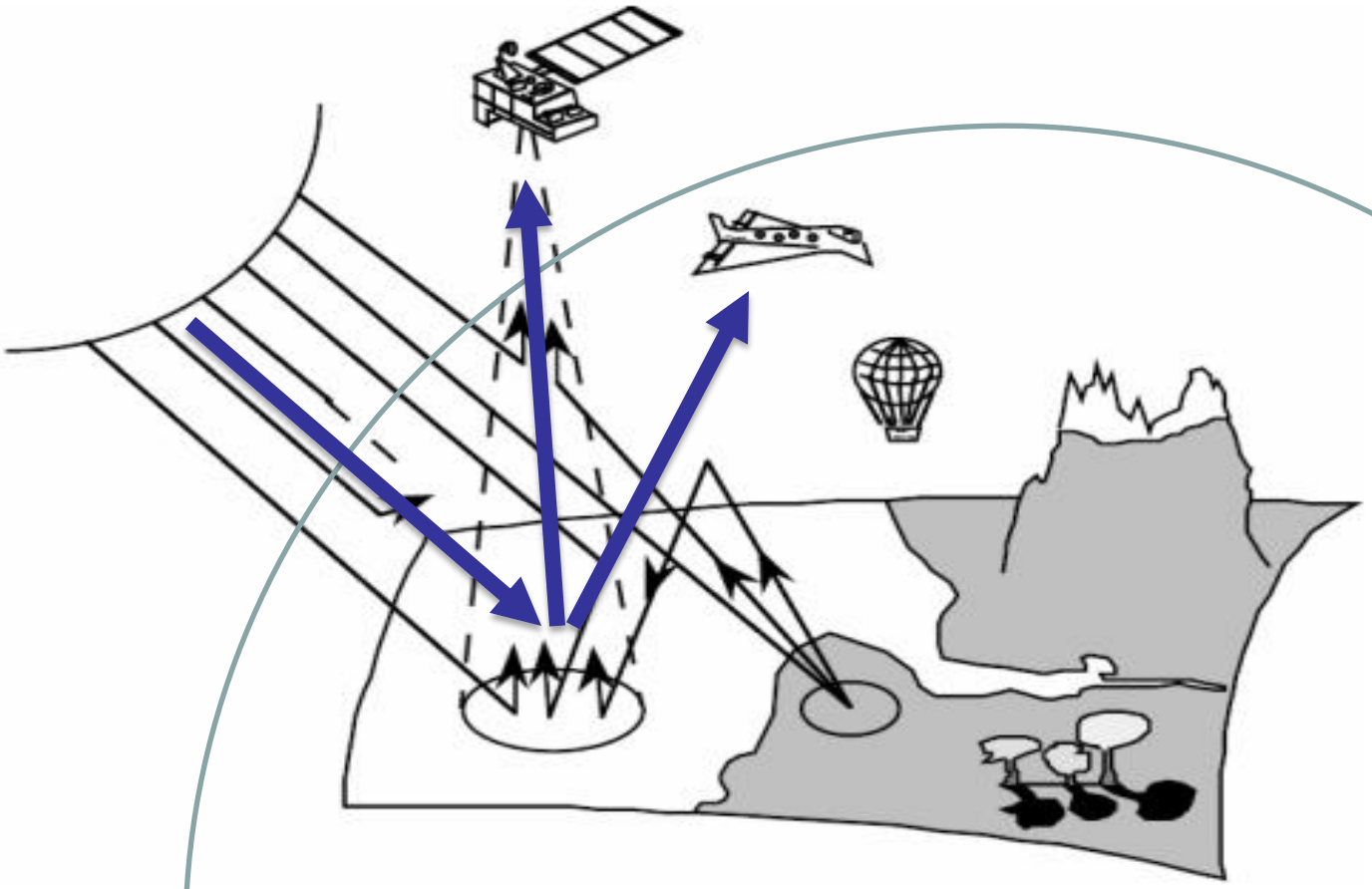
- The measurement of diffuse-to-global ratios
- Reduce the error caused by assuming the aerosol types

3.Method

Improvement :

For satellite sensor

For UAV sensor



3.Method

Improvement :

Irradiance-based method use for satellite sensor

The total transmittance of solar path and view path

- $$\rho^*(\theta_s,\theta_v,\phi_{v-s}) = \rho_a(\theta_s,\theta_v,\phi_{v-s}) + \frac{\rho_t}{1-s\cdot\rho_t}\cdot T(\theta_s)\cdot T(\theta_v)$$

  ρ^*: TOA reflectance; ρ_a: Molecular and aerosol contribution; ρ_t: Atmospheric albedo

  $$T(\theta_v) = \frac{(1-\rho s)e^{-\delta/\mu_v}}{1-\alpha_v}$$

  $$T(\theta_s) = \frac{(1-\rho s)e^{-\delta/\mu_s}}{1-\alpha_s}$$

- $$\rho^* = \rho_a + \frac{e^{-\delta/\mu_s}}{1-\alpha_s}\cdot\rho(1-\rho s)\cdot\frac{e^{-\delta/\mu_v}}{1-\alpha_v}$$

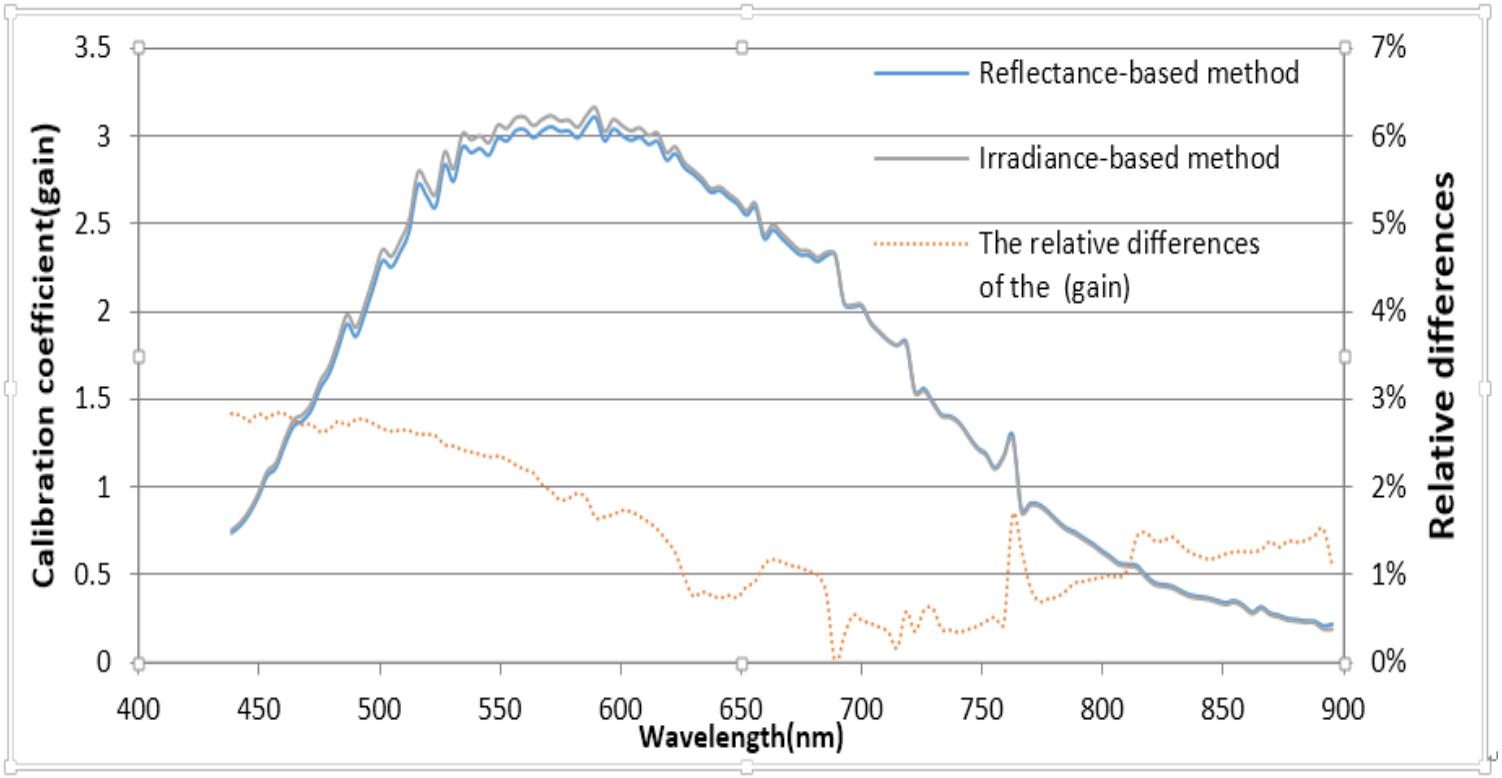
Irradiance-based method use for UAV sensor

$$L = L_a + \frac{\rho}{1-\rho S}\cdot\frac{E_0\mu_s}{\pi d^2}\cdot\frac{(1-\rho_c S)e^{-\delta/\mu_s}}{1-\alpha_s}\cdot T(\theta_v)$$

- Only the total transmittance of the solar path was substituted,
- The total transmittance of the view path was not change.

4.Results and analysis

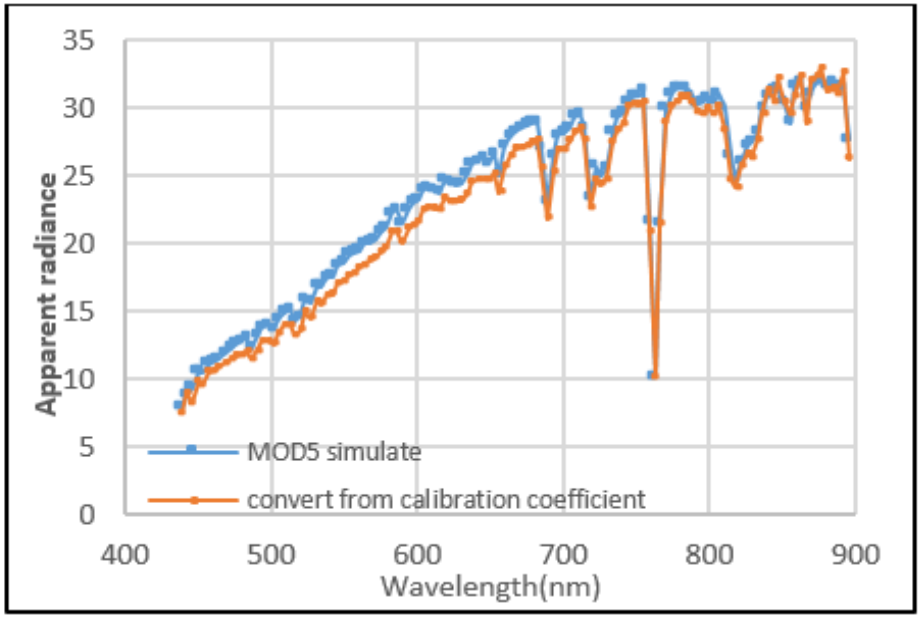
Calibration_coefficients_:



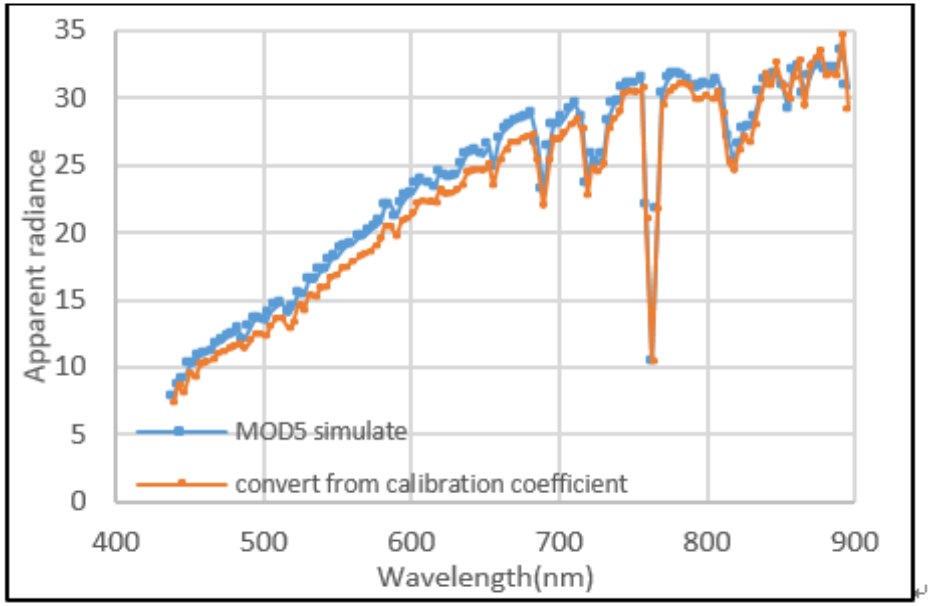
The calibration coefficients (gain) for the reflectance-based and the irradiance-based methods and their relative difference

4.Results and analysis

The apparent radiances of the runway cement:



(a)

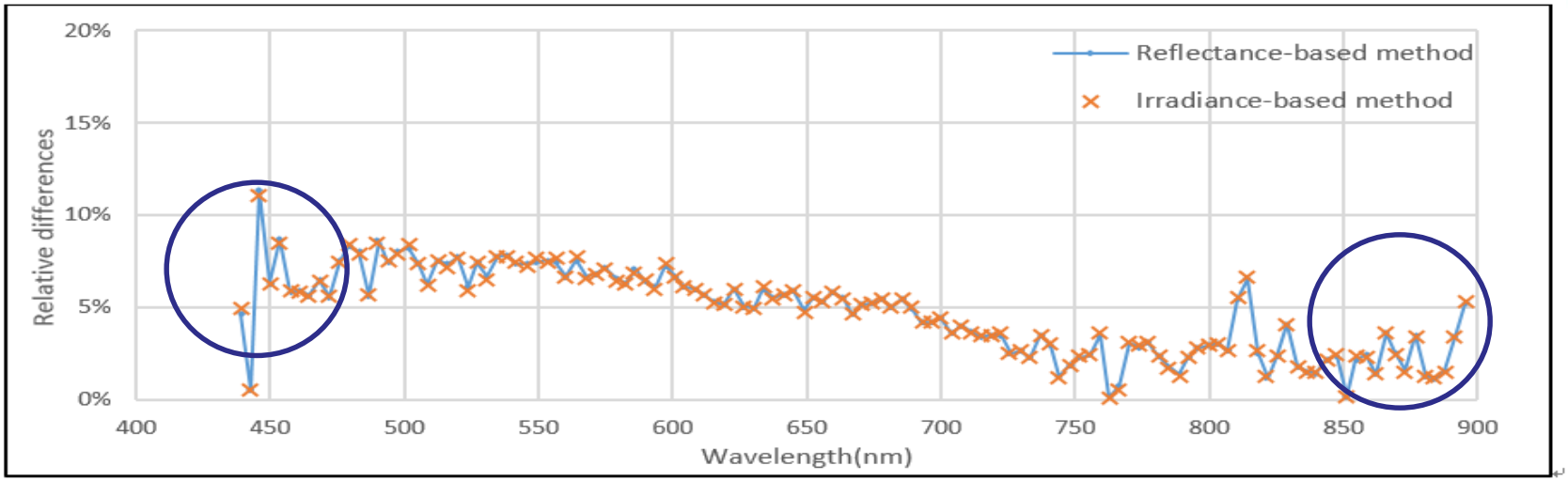


(b)

The apparent radiances of the reflectance-based(a) and the irradiance-based method(b)

4.Results and analysis

The different wavelength ranges:



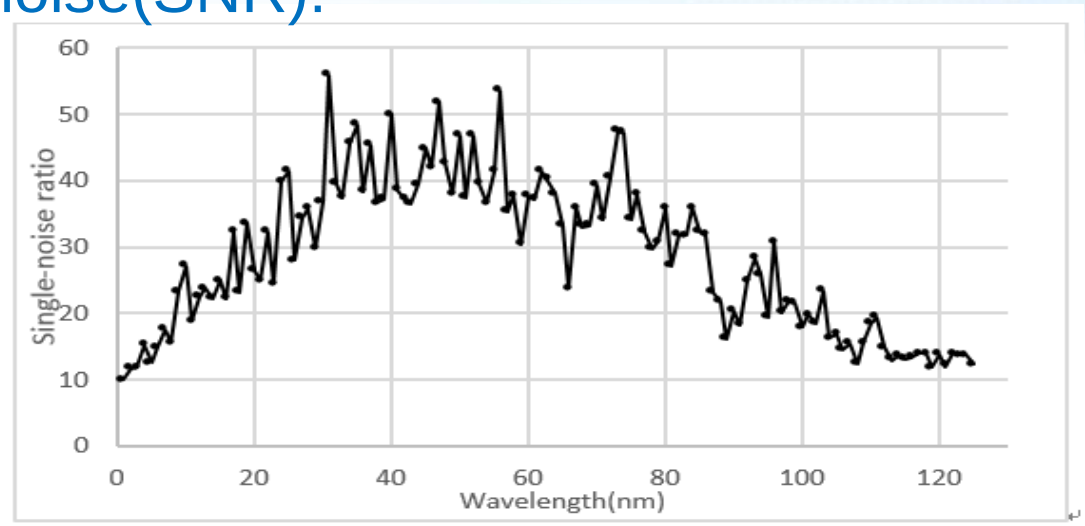
The relative differences for the reflectance-based and the irradiance-based method

The average relative differences for the different wavelength ranges

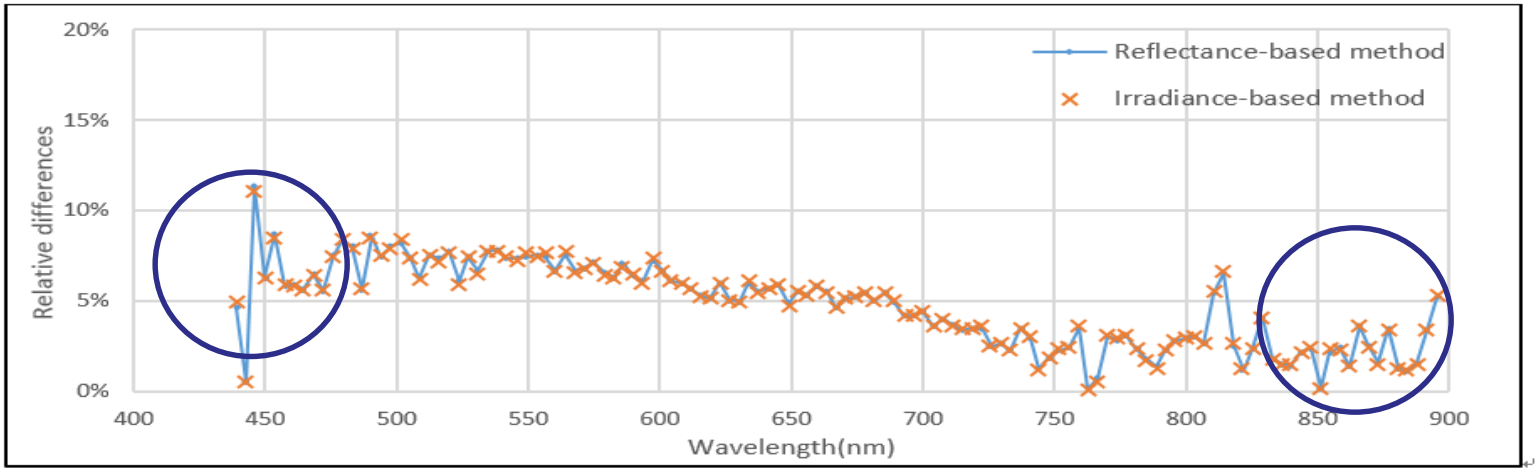
Band	Wavelength range(nm)	Average for the reflectance-based method	Average for the irradiance-based method
1~17	400~500	6.71%	6.62%
18~58	501~650	6.59%	6.57%
60~125	651~900	3.09%	3.09%
---	Total bands	4.74%	4.72%

4.Results and analysis

Signal-to-noise(SNR):



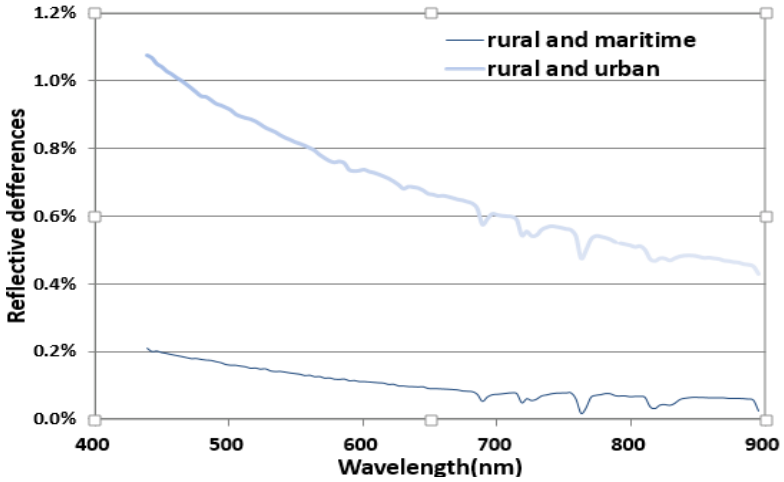
The SNR of calibration traps for each band



The relative differences for the reflectance-based and the irradiance-based method

4.Results and analysis

Analysis of uncertainty :



The relative differences for the Different aerosol type hypothesis(a: reflectance-based method; b: irradiance-based method

Source	Uncertainty (%)
Ground reflectance measurement	2.1
Optical depth measurement	1.1
Absorption computation	1.3
Assumption of aerosol type	0.40
Vertical distribution	1.0
Inherent code accuracy	0.6
Uncertainty in the value of μ_s	0.2
Total uncertainty (root sum of squares)	3.0

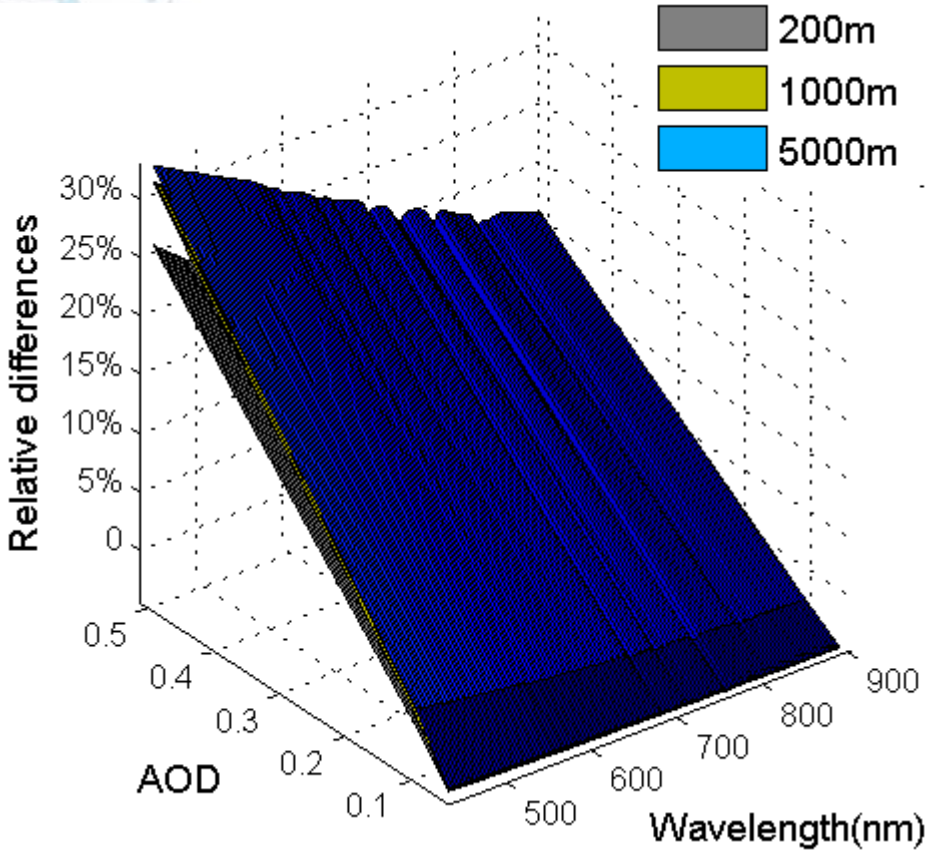
Estimated uncertainty reflectance-based method

Source	Uncertainty (%)
Ground reflectance measurement	2.1
Optical depth measurement	1.1
Assumption of aerosol type	0.53
Inherent code accuracy	0.6
Uncertainty in the value of μ_s	0.1
Diffuse-to-global irradiance measurement	1.0
Total uncertainty (root sum of squares)	2.69

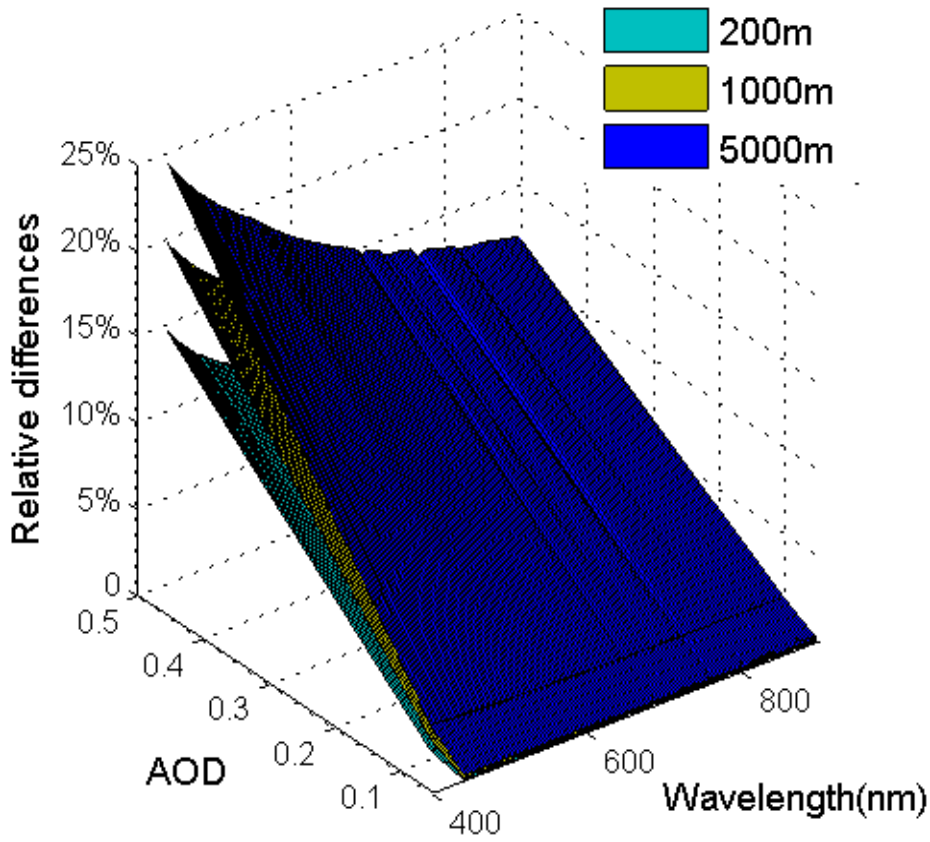
Estimated uncertainty irradiance-based method

S. F. Biggar, "In-flight methods for satellitesensor absolute radiometric calibration," 1990.

4.Results and analysis



the reflectance-based method



the improved irradiance-based method

4.Results and analysis

The average relative differences between two aerosol types for each case of all bands

--	reflectance-based method (%)			irradiance-based method (%)		
--	5000m	1000m	200m	5000m	1000m	200m
AOD 0.05	0.79	0.68	0.57	0.29	0.19	0.1
AOD 0.1	4.06	3.48	2.93	1.57	1.03	0.56
AOD 0.5	28.78	26.09	21.72	16.32	12.92	8.94

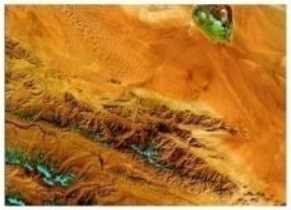
- The improved method has lower relative differences for each case
- With the increasing of height and AOD, the effective is more obvious
- When the AOD is small, this effective is not obvious due to the little impact of aerosol on the radiance transfer.

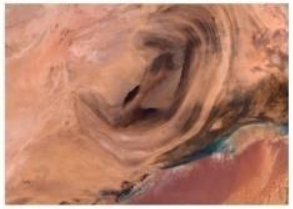
Conclusion

- We present an improved irradiance-based method which is considered the different of radiative transfer path between the UAV and satellite.

- According to the characteristics of the UAV platform, compared with reflected-based method, the improved irradiance-based method can ensure the calibration accuracy more reliable and more suitable for UAV sensor vicarious calibration.

Thanks!



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