EXPERIMENTAL STUDY ON WATER VAPOR AMOUNT CALCULATION USING 940 nm ABSORPTION SPECTRAL BAND

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Abstract

Atmospheric water vapor amount is an important parameter in weather and climate study. Since using infrared and microwave spectral band to detect water vapor amount have some difficulties [1], scientists in the world have to investigate the possibility of using visible, near infrared spectral band [2][3][4][5]. We did some researches in this field using both simulated and real satellite data. The results indicate that it is possible to retrieve water vapor amount from near infrared satellite data and the results are good consistent. with the radiosonde.

DATA AND INFORMATION

a) 6 channels

Table 1 Channel Performance

No of channel	CH1	CH2	CH 3	CH 4	CH5	CH6
Wavelength (nm)	893-913	913-933	933-953	953-973	853-873	1013-1033
absorption	Weak	Weak	Strong	Weak	window	window

b) 6 Standard Atmosphere Profiles:
tropical ,mid-latitude summer ,mid-latitude winter ,sub-arctic summer ,sub-arctic winter and U. S. standard atmosphere.

c) Surface Reflectance:
- 0.1~ 0.5 for land
- 0.05~ 0.1 for ocean

d) Aerosol Type: Land and Ocean
visibility: 5km, 23km, 50km

WATER VAPOR CHANNEL TRANSMITTANCE COMPUTATION

Table 2 Water Vapor Channel Transmittance (Visibility: 23km)

Observation Height (KM)	Mid-latitude							
	Summer				Winter			
	CH1	CH2	CH 3	CH 4	CH1	CH2	CH3	CH 4
1.5	0.81791	0.77003	0.39606	0.65607	0.91425	0.90085	0.63159	0.83524
3.0	0.77083	0.71242	0.32644	0.58996	0.89946	0.86087	0.55339	0.78042
10.0	0.74224	0.67898	0.29457	0.55572	0.85397	0.83229	0.51166	0.74579
Space	0.74026	0.67716	0.29374	0.55431	0.85182	0.83022	0.51030	0.74399

From Table 2:
- Transmittances for all the channels >29%
- Water vapor absorption mostly occurs in the troposphere
- Transmittances in winter are slightly higher than that in summer
- Water vapor channels carries column water vapor information

SENSIBILITY STUDIES

a) Variation of Water Vapor Channel Reflectance with Solar Zenith Angle(Fig.1)

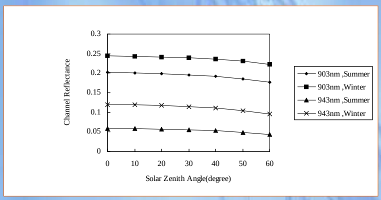

Fig.1 (a) Land in Mid-latitude (visibility: 23km)

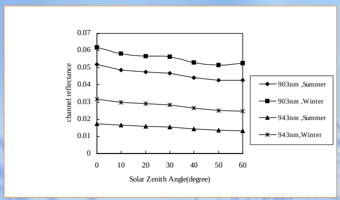

Fig.1 (b) Ocean (visibility: 23km)

b) Variation of Water Vapor Channel Reflectance with Surface Reflectance (Fig.2),U. S. standard atmosphere profile Solar zenith angle: 40° ,Visibility: 23km

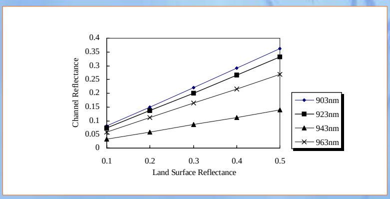

Fig.2 (a)

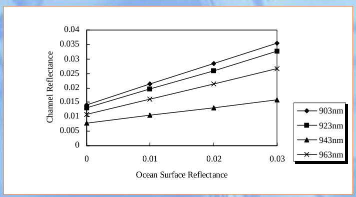

Fig.2 (b)

c) Water Vapor Channel Reflectance in Different Atmospheric Temperature and Moisture Profiles.
Conditions:
- Solar zenith angle: 40°
- Land surface reflectance :0.3
- Ocean surface reflectance :0.05
- Visibility :23 km
- Water vapor amount for different atmospheric moisture profile
  - _Tropical atmosphere: 4.120cm
  - _Mid-latitude summer atmosphere(Midl. summer): 2.930cm
  - _Mid-latitude winter atmosphere(Midl. winter): 0.853cm
  - _Sub-arctic summer atmosphere(Subar. summer): 2.102cm
  - _Sub-arctic winter atmosphere(Subar. winter): 0.419cm
  - _U. S. standard atmosphere(US standard): 1.424cm

From Fig3:
- The higher total water vapor content, the smaller channel reflectance
- The lowest channel reflectance is in tropical atmosphere, the highest channel reflectance is in sub-arctic winter atmosphere

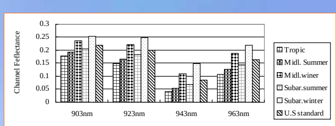

Fig.3 (a) Land

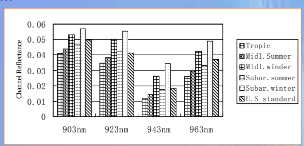

Fig.3 (b) Ocean

d) Reflectance for Two Channels in Different Water Vapor Amount and Same Atmospheric Temperature Profile
Conditions :
- Solar zenith angle :40°
- Land surface reflectance :0.3
- Visibility :23 km
- U. S. Standard atmosphere profile
- Water vapor amount : 0.7cm, 1.4cm, 2.5cm, 2.9cm and 4.1cm
- Channels : 903nm (weaker absorption
- 943nm (stronger absorption)

Taking 903nm(CH1) as a example, we know that the variation of CH1 reflectance with atmospheric profiles is from 0.18 to 0.25 shown in Fig. 3(a), but the variation of CH1 reflectance with water vapor is almost 0.18 to 0.25 in Fig.4. It shows that water vapor effect on the reflectance of 903nm (CH1) is larger than atmospheric temperature. CH3 (943nm) reflectance are more sensitive than CH1 (903nm) in the dry area .

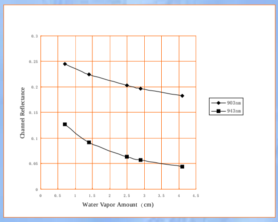

Fig. 4 The Variation of Reflectance with water vapor Amount

e) Sensitivity of Water Vapor Channel Reflectance to Aerosol

Table3 Calculating Channel Reflectance and Radiance (Solar zenith angle 40°)

	Visibility		Mid-latitude							
			Summer				Winter			
			CH1	CH2	CH3	CH4	CH1	CH2	CH3	CH4
Surface Reflectance ρ=0.1	5km	ρ *	0.0721	0.0621	0.0216	0.0468	0.0876	0.0824	0.0421	0.0690
		L	16.952	13.993	4.661	9.689	20.615	18.674	9.082	14.272
	23km	ρ *	0.0703	0.0608	0.0213	0.0463	0.0855	0.0807	0.0414	0.0681
		L	16.541	13.713	4.596	9.573	20.109	18.195	8.940	14.094
	50km	ρ *	0.0703	0.0608	0.0213	0.0463	0.0854	0.0807	0.0414	0.0682
		L	16.526	13.707	4.596	9.578	20.092	18.188	8.940	14.100
Surface Reflectance ρ=0.5	Visibility		Mid-latitude							
			Summer				Winter			
			CH1	CH2	CH3	CH4	CH1	CH2	CH3	CH4
	5km	ρ *	0.2777	0.2398	0.0755	0.1819	0.3411	0.3230	0.1599	0.2737
		L	65.323	54.055	16.306	37.628	80.240	72.826	34.528	56.624
	23km	ρ *	0.3162	0.2728	0.0854	0.2065	0.3886	0.3677	0.1816	0.3110
		L	74.392	61.502	18.451	42.719	91.418	82.909	39.214	64.346
	50km	ρ *	0.3221	0.2778	0.0869	0.2102	0.3958	0.3745	0.1849	0.3166
		L	75.770	62.631	18.776	43.489	93.115	84.438	39.924	65.513

From Table3 we got :
- Aerosol effect on the reflectance is very small when visibility is greater than 20km
- Changes of the reflectance for the most channels are significant when the visibility decreases from 23km to 5km

RETRIEVAL OF TOTAL WATER VAPOR CONTENT

Algorithm
the radiance L observed by near infrared channel of satellite can be written as :

$$L = L_s \rho_e \tau + L_p \quad (1)$$

Where Ls = solar radiation above the atmosphere, Lp =the path scattered radiation, ρ e = Surface reflectance, τ =atmospheric transmittance . The first item in the right-hand of Eq. (1) is the direct solar radiation reflected by surface and atmosphere . Lp and τ include water vapor information. Question is how to get total water vapor content from the satellite measurement L ?

When visibility is greater than 20km , Equation(1) can be written as :

$$L = K L_s \rho_e \tau \quad (2)$$

The two sides of eq. (2) is divided by Ls , then

$$\rho^* = K \rho_e \tau \quad (3)$$

For window channel : $\rho^*_0 = K_0 \rho_{e0} \tau_{a0}$ (4)

For water vapor channel : $\rho^*_w = K_w \rho_{ew} \tau_{aw} \tau_w$ (5)

Where ρ * is channel reflectance, τ aw and τ w are aerosol transmittance and water vapor transmittance of the channel respectively. Eq.(5) is divided by eq.(4) and based on molecule spectroscopy theory[3]

$$\tau_w = e^{-\alpha \sqrt{m}} \quad (6)$$

$$\ln B = \beta - \alpha \sqrt{m} \quad (7)$$

Where m is water vapor amount , coefficient $\beta = \ln(K_w \rho_{ew} \tau_{aw} / K_0 \rho_{e0} \tau_{a0})$, $B = \rho^*_w / \rho^*_0$ can be known from satellite measurements . If coefficients α and β were known , m would be retrieved .

Coefficients α and β can be calculated by two ways : 1. According to eq. (7) using conventional radiosonde data and simulated 'B' by radiation transfer model to make regress analyses ; 2. According to eq. (7) using conventional radiosonde data and 'B' obtained from satellite measurements to make regress analyses . α and β depend on regions and seasons .

Retrievals for Two Cases

Case 1: using the way '1' to get α and β , then to retrieval 'm'
Data : atmospheric profiles and surface reflectance are same as indicated in the section 1.
solar zenith angle 0° ~ 60° , interval 10°
aerosol type: land and ocean ; visibility 23km
Total samples are 294, 290 of them are used for computing coefficients α and β ,the others are used for retrieval .
The results are shown in Table 4.

Table 4 Retrieved Water Vapor Amount Using CH1/CH5

		Midlatitude Summer	Midlatitude Winter
Retrieved m′	Land	6.350	1.956
	Ocean	6.324	1.929
Average Value of m′		6．337	1.943
Ground Truth m		6．313	1.967
Relative Error		-0.4%	+1.2%

Case 2 : Data from FY-1C channel 2 (840nm-880nm) ,channel 10 (900nm-965nm) in June~July 2000, and co-located radiosonde data in the same time, are used to get α and β . Then these coefficients are used to retrieve the water vapor amount with FY-1C channel 2, channel 10 data on May 13 of 2001 . the results are shown in Fig. 5 .

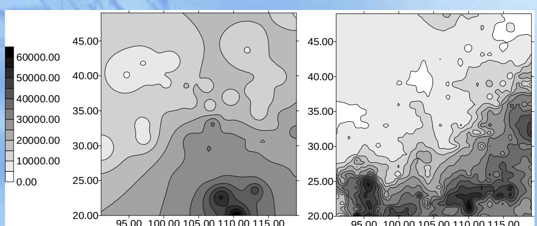

Fig.5 Column water vapor (a) Ground truth (b) Retrieval

The results from Fig.5. (a) and (b) are comparable .

CONCLUSION

In this paper, the experimental studies show that the near infrared spectral channels can provide atmospheric column water vapor information, the retrieval results from both simulated data and FY-1C satellite observations are good consistent with the radiosonde.

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