EFFECTS OF ATMOSPHERIC CORRECTION ON RETRIEVING LAND SURFACE TEMPERATURE USING AVHRR DATA

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1. INTRODUCTION

For accurate determination of land surface temperature from satellite measurements, one severe obstacle is related to the coupling between the surface temperature and emissivity, to deal with this problem, two algorithms have been proposed, in which a set of two or three channel measurement data, such as AVHRR channels 4, 5 and 3, made at two different times are used. Simulation results show that with these two algorithms land surface temperatures could be determined rather accurately, if the atmospheric effect could be omitted. In real situations, the atmospheric effect is not negligible, for any retrieval algorithm of practical use, the atmospheric effect must be taken into consideration. In fact, the atmospheric effect constructs another main difficulty in the determination of land surface temperatures. In retrieving land surface temperatures with two or three AVHRR channels, the most practical way to make atmospheric correction is to utilize atmospheric temperature and moisture profiles obtained from collocated TOVS/ATOVS data. But, because of the unavoidable errors in retrieved atmospheric temperature and moisture profiles, the atmospheric correction can never be perfect, that will affect the accuracy of land surface temperature determination, finally. The problem is if these two algorithms are still useful in such cases. Because of the non-uniformity of land surface and no enough necessary in situ measurement data of land surface temperature, it is difficult to validate the results of land surface temperature retrieval using real satellite measurement data. So that, simulations are used to investigate the effects of imperfect atmospheric correction resulted from using atmospheric temperature and moisture profiles with different extent errors on land surface temperature retrieval with these two algorithms and to see the possibility for their practical application.

2. ALGORITHMS

On the basis of radiative transfer theory, the radiance I_i measured in a channel from a satellite-bone infrared sensor for a cloudless atmosphere can be simply expressed as

$$I_i = \varepsilon_i B_i(T_s)\tau_{si} + \rho_i \tau_{si} I_{Di} + I_{Ui} \quad (1)$$

here, ε is the surface emissivity, ρ the surface reflectance, for isotropic surface, ρ = 1- ε , B is the Planck radiance, T_s the surface temperature, τ_s is the path transmittance from the surface to the satellite, I_D is the effective atmospheric downward radiance, and I_U is the upward atmospheric path radiance, the subscript i means that the quantities are weighted average ones considering the response function of channel i. With the necessary atmospheric parameters obtained, the atmospheric transmittance τ_s, the downward and upward radiances, I_D and I_U, can be determined through radiative transfer calculation. The surface upgoing radiance, I_{gi} can be expressed as

$$I_{gi} = \varepsilon_i B_i(T_s) + (1-\varepsilon_i) I_{Di} \quad (2)$$

$I_{gi} = (I_i - I_{Ui}) / \tau_s$ can be calculated from measured and calculated quantities, hence, in Eq.(2), there are two unknowns, the land surface emissivity ε_i and temperature T_s.

2.1 Two channel algorithm

When the surface emissivities are not changed at two continuous measurement times, $\varepsilon_{ij} = \varepsilon_i$ (i =1,2; j =1,2), similar to Eq.(2), the surface upgoing radiances can be expressed as

$$I_{gij} = \varepsilon_i B_i(T_{sj}) + (1-\varepsilon_i) I_{Dij} \,, \qquad i = 1, 2 \;;\; j = 1, 2 \quad (3)$$

here, i refers to channel, j to measurement time. In the system of four equations represented by Eq.(3), I_{gij} can be obtained from satellite measured radiances after atmospheric correction, the downward radiance I_{Dij} can be calculated with necessary atmospheric parameters provided. Hence, there are four unknowns, two land surface emissivities ε_i for two channels (i =1,2) and two surface temperatures T_{sj} at two measurement times (j =1,2), and four independent equations, after canceling two emissivities, a system of two equations having two land surface temperatures can be obtained and solved with an iterative procedure.

2.2 Three channel algorithm

When there are some variations of land surface emissivities at two continuous measurement times, the aforementioned two channel algorithm would not be able to determine land surface temperatures and emissivities exactly. In that cases, a three channel algorithm, in which a pair of three channel measurements made at two continuous times are used, can be applied to determine the surface temperatures and emissivities, simultaneously, if the surface emissivities are varied with similar proportionality for different channels. Similar to Eq.(3), the surface upgoing radiance for *i*th channel and *j*th measurement can be expressed as

$$I_{gij} = \varepsilon_{ij} B_i(T_{sj}) + (1-\varepsilon_{ij}) I_{Dij}, \qquad i = 1, 2, 3; \quad j = 1, 2 . \tag{4}$$

Because the proportionalities of emissivities at two measurement times for the three channels are assumed to be equal, i.e. $\varepsilon_{i2}/\varepsilon_{i1} = c_i = c$ (i =1,2,3), there are six unknowns in Eq.(4), two surface temperatures, three emissivities and a proportional constant, they could be determined through solving the system of six equations expressed by Eq.(4).

3. ATMOSPHERIC EFFECT

3.1 Analysis

For land surface temperature determination, AVHRR channels 3, 4 and 5 can be used. They are located in the infrared window region, the downward and upward radiances in Eq. (1), I_D and I_U , are mainly determined by the atmospheric temperature and moisture profiles. With the atmospheric temperature and moisture profiles retrieved from collocated TOVS data, the atmospheric transmittance τ_s , the downward and upward radiances, I_D and I_U , can be determined through radiative transfer calculation. But, there are usually uncertainties in atmospheric parameters obtained and in radiative transfer model, thus there are always some errors in calculated quantities, τ_s , I_D and I_U, and that will finally affect the accuracies of land surface temperature and emissivity derived. From Eq. (1), we can obtain

$$\Delta I = ((B(T_s) - I_D)\Delta\varepsilon + \varepsilon \frac{\partial B(T_s)}{\partial T}\Delta T_s)\tau_s + (\varepsilon B(T_s) + (1-\varepsilon)I_D)\Delta\tau_s + (1-\varepsilon)\tau_s \Delta I_D + \Delta I_u , \tag{5}$$

in which, $\Delta I = 0$, because I is given as a measured upwelling radiance at the top of the atmosphere. Thus, in order to keep the equation valid, usually, there will be deviations of land surface temperature and emissivity, ΔT_s and $\Delta\varepsilon$, from their true values to compensate the effects of uncertainties in upgoing path radiance, downward effective radiance and transmittance, ΔI_U , ΔI_D and $\Delta\tau_s$. Table 1 shows the deviations of land surface temperature and emissivity, which may be caused by errors in atmospheric transmittance and radiances, corresponding to AVHRR channels 4 and 5 for midlatitude summer and winter atmospheres with land surface temperatures, 294.2 K and 272.2 K, respectively, and emissivities fixed at 0.90 and 0.98 for both channels, respectively. In Table 1, ΔT_{su}, ΔT_{sD} and $\Delta T_{s\tau}$ refer to land surface temperature deviations calculated with $\Delta I = 0$ and $\Delta\varepsilon = 0$ from Eq. (5) for 1% increase in upgoing path radiance, downward effective radiance and transmittance, respectively, and ΔT_s is the total change caused by them; $\Delta\varepsilon_u$, $\Delta\varepsilon_D$ and $\Delta\varepsilon_\tau$ express land surface emissivity deviations computed with $\Delta I = 0$ and $\Delta T_s = 0$ from Eq. (5) for 1%

Table 1. Effects of 1% deviations in atmospheric upgoing path radiance, effective downward radiance and transmittance on land surface temperature and emissivity

Atm	MS		MW	
ch.	5	4	5	4
		ε_s=0.90		
$\Delta Tsu(K)$	-0.479	-0.263	-0.080	-0.054
$\Delta TsD(K)$	-0.044	-0.032	-0.014	-0.011
$\Delta Ts\,\tau$ (K)	-0.030	-0.018	0.012	-0.002
ΔTs (K)	-0.553	-0.312	-0.083	-0.067
$\Delta\varepsilon_u$	-0.0144	-0.0067	-0.0015	-0.0011
$\Delta\varepsilon_D$	-0.0013	-0.0008	-0.0003	-0.0002
$\Delta\varepsilon\,\tau$	-0.0009	-0.0005	0.0002	0.0000
$\Delta\varepsilon$	-0.0166	-0.0079	-0.0016	-0.0013
		ε_s=0.98		
$\Delta Tsu(K)$	-0.440	-0.241	-0.074	-0.050
$\Delta TsD(K)$	-0.008	-0.006	-0.003	-0.002
$\Delta Ts\,\tau$ (K)	-0.073	-0.070	-0.062	-0.071
ΔTs (K)	-0.521	-0.317	-0.138	-0.123
$\Delta\varepsilon_u$	-0.0144	-0.0067	-0.0015	-0.0011
$\Delta\varepsilon_D$	-0.0003	-0.0002	-0.0001	0.0000
$\Delta\varepsilon\,\tau$	-0.0024	-0.0019	-0.0013	-0.0016
$\Delta\varepsilon$	-0.0171	-0.0088	-0.0029	-0.0027

Table 2. 8 groups of different errors in atmospheric temperature and moisture profiles considered in land surface temperature and emissivity determination

group	ΔT(K)	ΔW(%)	rmsT	rmsW
1	(-1.0 , 1.0)	(-5.0 , 5.0)	0.587K	2.94%
2	(-1.0 , 1.0)	(-10.0,10.0)	0.587K	5.88%
3	(-2.0 , 2.0)	(-10.0,10.0)	1.174K	5.88%
4	(-2.0 , 2.0)	(-15.0,15.0)	1.174K	8.82%
5	(-2.5 , 2.5)	(-20.0,20.0)	1.468K	11.76%
6	(-3.0 , 3.0)	(-30.0,30.0)	1.762K	17.64%
7	(-2.0 , 0.0)	(-20.0,0.0)	1.174K	11.76%
8	(0.0 , 3.0)	(0.0, 30.0)	1.762K	17.64%

increase in upgoing path radiance, downward effective radiance and transmittance, respectively, and $\Delta\varepsilon$ is the total change caused by them. Table 1 shows that the land surface temperature and emissivity deviations, ΔTs and $\Delta\varepsilon$, in Eq.(5) caused by errors in calculation of atmospheric downward and upward radiances and transmittance are different for different channel, and the largest effect of atmospheric correction comes from the errors in calculations of atmospheric upwelling path radiances.

The results shown in Table 1 imply that when aforementioned two or three channel algorithms are used for land surface temperature retrieval, even if the assumptions of channel emissivities not varied or varied with same proportionality for different channel at two measurement times are valid for the true land surface emissivities, because of imperfect atmospheric correction, the apparent or say equivalent land surface emissivities in Eqs.(3) and (4) may not follow the assumptions. In such circumstances, can the land surface temperatures be determined with acceptable accuracy by the use of these two algorithms?

3.2 Retrieval test

In order to investigate the effects of imperfect atmospheric correction on land surface temperature retrieval with two or three channel algorithms, retrieval tests have been carried out by considering different extent errors in atmospheric temperature and moisture profiles in atmospheric correction. A total amount of 480 sets of simulated measurement data are used to retrieve land surface temperatures and emissivities with two and three channel algorithms, respectively. According to random absolute errors, ΔT, in the atmospheric temperature profiles and random relative errors, ΔW, in atmospheric moisture profiles, they are divided into eight groups, each group includes 60 sets of measurements. The eight groups are listed in Table 2, in which rmsT and rmsW are root mean square errors corresponding to randomly distributed absolute deviations of temperature, ΔT, and relative deviations of moisture, ΔW, in atmospheres, respectively. As examples, by taking errors in atmospheric temperature and moisture profiles as in group 4 into consideration in atmospheric correction, for 60 sets of measurements included, the resulted root mean square relative errors in equivalent atmospheric downward radiances, upward atmospheric path radiances and transmittances are 1.45%, 1.56% and 0.79%, respectively, for AVHRR channels 4 and 5, and 1.54%, 1.57% and 0.65%, respectively, for AVHRR channels 3, 4 and 5. Given in Table 3 are the deviations in land surface temperatures, ΔTs, obtained by the use of two channel algorithm from sixty sets of simulated measurement data included in group 4, rmsTs and rmsε_s are root mean square errors of retrieved land surface temperatures and emissivities, respectively. Similar results obtained with three channel algorithm are given in Table 4. Because the land surface emissivities for the three AVHRR channels are assumed to be not

Table 3. Deviations of land surface temperatures retrieved with two channel algorithm taking the errors of atmospheric temperature and moisture shown in group 4 into consideration

ΔTs											
-1.295	-.9099	-1.535	-.1852	.2803	.1476	-.2765	1.180	.5036	.6455	-.9722	-.1240
-.8521	-.6794	-1.435	-.4330	.2792	.0783	-.4262	1.005	.6226	.8167	-1.156	-.0293
-1.128	-.9301	-2.651	-.4653	-.7277	-.0842	-.5117	1.144	.4164	.5517	-1.331	-.2326
-.7062	-.5845	-2.278	-.6617	-.6203	-.1251	-.6746	1.073	.6527	.8318	-1.482	.0008
-1.493	-.9257	-1.493	.1236	-.4198	.9278	-.3037	1.170	.5198	.6970	-.8864	-.0612
-.9057	-.6547	-1.396	-.0833	-.3508	.9370	-.3885	.9833	.6247	.7607	-1.035	-.0482
-2.078	-1.614	-1.629	-.6309	-.4957	-.1210	-.2065	.4739	-.0424	.5085	-2.419	-.2968
-1.996	-1.312	-1.485	-.8461	-.4241	-.1723	-.2624	.2526	.0789	.7414	-2.665	-.1267
-1.044	-.8497	-2.557	-.0669	-.7204	.3081	-.0868	.5411	.4783	.6711	-.9182	-.1201
-.8155	-.6345	-2.294	-.2893	-.6163	.2592	-.2337	.4750	.6446	.8142	-1.023	-.0180
$rmsT_S$=0.96 K							$rms\varepsilon_S$=0.0184				

Table 4. Deviations of land surface temperatures retrieved with three channel algorithm taking the errors of atmospheric temperature and moisture shown in group 4 into consideration

ΔTs											
-1.530	-.7517	-.9841	-1.043	.2809	.4000	-.1520	.3606	.4269	1.222	-.9455	.7763
-.8940	-.6037	-.9362	-1.449	.2814	.3833	-.2495	.3748	.5255	1.567	-1.125	1.119
-1.425	-.7693	-1.038	-.6683	.0737	.3839	-.2765	.3098	.3565	1.131	-.9136	.6603
-.7984	-.5144	-.8947	-.9433	.1149	.5444	-.8589	.4255	.5927	1.584	-1.017	1.141
-1.652	-.7641	-.9450	.3561	.2817	.2881	-.1381	.4018	.4695	.3122	-.8997	.8450
-.9251	-.5814	-.8997	.1217	.2924	.1978	-.1406	.3849	.5474	.4675	-1.102	1.105
-1.253	-.7453	-1.071	-.7230	.1582	.3369	-.0613	.8083	.3162	1.087	-1.063	.5917
-1.191	-.8246	-.9843	-.9845	.1754	.4850	-.0512	.5522	.4004	1.492	-1.214	1.018
-1.373	-.7000	-.9968	.1447	.1527	.3792	.0506	.6058	.4266	1.242	-.867	.784
-.8754	-.5601	-.8982	.1310	.1846	.3479	-.0138	.5524	.5801	1.570	-1.019	1.134
$rmsT_S$=0.80 K							$rms\varepsilon_S$= 0.0234				

varied at two measurement times, if there were no errors in atmospheric correction, the exact land surface temperatures and emissivities could be obtained with any one of the above two retrieval algorithms. So that the retrieval errors in Tables 3 and 4 show the atmospheric effects on land surface temperature and emissivity retrieval with these two algorithms.

Similar to above case, but the atmospheric temperature and moisture are systematically lower than true values, i.e. the absolute random error ΔT between -2.0K and 0.0K and the relative random error ΔW between -20% and 0% at each level in atmospheres, the corresponding root mean square errors are rmsT=1.174K and rmsW=11.76%, respectively, as shown by group 7 in Table 2. In making atmospheric correction, the resulted errors in equivalent atmospheric downward radiances, upward atmospheric path radiances and transmittances are significantly larger, their relative root mean square errors are 7.79%, 8.53% and 4.36%, respectively, for AVHRR channels 4 and 5, and 7.62%, 8.17% and 3.62%, respectively, for AVHRR channels 3, 4 and 5. The retrieval results of land surface temperature for each sixty sets of measurements with two channel and three channel algorithms are given in Tables 5 and 6, respectively. With three and two channel algorithms, the retrieval results of land surface temperature and emissivity for each 60 sets of measurements in eight groups with different atmospheric temperature and moisture deviations randomly distributed at different levels in atmospheres are summarized in Table 7 and 8, in which 'rmsRu', 'rmsRd' and 'rmst' are resulted root mean square relative errors of calculated equivalent atmospheric downward radiances, upward atmospheric path radiances and transmittances, and '$(\text{rmses})_a$' expresses the root mean square deviation of apparent land surface emissivities in channels obtained from Eqs.(3) or (4) with true land surface temperature and calculated equivalent atmospheric downward radiances, upward atmospheric path radiances and transmittances, and the last three columns are root mean square errors of retrieved land surface emissivities and temperatures, and the maximum deviation of retrieved land surface temperature. Table 8 shows for total 480 sets of measurements included in eight groups, the root mean square errors of retrieved land surface emissivity and temperature, and the maximum deviation of retrieved land surface temperature, rmse_s, rmsTs and ΔTsmax, are 0.0182, 0.91K and -3.61K, respectively; compared with them, if the land surface emissivity e_s is assumed as a known quantity and has the value of 0.96 in determination of land surface temperatures, the above three quantities will be significantly larger and equal to 0.0316, 1.38K and -4.68K, correspondingly. From tables 3 to 8, it can be seen that because of atmospheric effect, the land surface temperatures and emissivities can no longer be determined exactly as in the case of no atmospheric effect, but reasonably accurate land surface temperatures and emissivities can still be obtained with two or three channel retrieval algorithms, and the retrieval results with three channel method are some what better than that with two channel method.

Table 5. Deviations of land surface temperatures retrieved with two channel algorithm taking the errors of atmospheric temperature and moisture shown in group 7 into **consideration**

ΔTs											
-.328	-.602	-1.90	-.740	1.24	-.225	.287	.958	1.22	1.02	-1.70	.092
-1.97	-1.86	-1.94	-.647	1.06	-.234	.707	.130	1.28	1.45	-1.97	.051
-.590	-.652	-1.14	-.794	1.24	-.252	.046	.891	1.21	.963	-1.70	.057
-1.83	-1.59	-1.20	-.742	1.09	-.254	.301	.194	1.31	1.37	-1.94	.076
-.829	-.731	-1.10	-.670	1.24	-.213	.158	.832	1.25	1.00	-1.67	.127
-1.31	-1.02	-1.06	-.737	1.11	-.236	.305	.433	1.38	1.34	-1.88	.180
-.008	-.478	-1.97	-.869	1.25	-.295	.604	1.05	1.16	1.05	-1.75	-.030
-1.13	-.911	-1.67	-.758	1.11	-.208	.444	.516	1.39	1.50	-1.87	.218
-.137	-.558	-1.21	-.903	1.24	-.317	.362	.969	1.16	.903	-1.75	-.048
-1.62	-1.45	-1.20	-.689	1.09	-.218	.527	.301	1.33	1.44	-1.93	.133
$rmsT_S$=1.08 K								$rms\varepsilon_S$= 0.0238			

Table 6. Deviations of land surface temperatures retrieved with three channel algorithm taking the errors of atmospheric temperature and moisture shown in group 7 into consideration

ΔTs											
-1. 99	-.473	-.704	-.602	.545	.513	-.719	.374	.856	1.03	-1.13	.341
-2. 05	-2.05	-.880	-.571	.465	.719	-.599	-.373	.867	1.47	-1.31	.354
-1.18	-.524	-.699	-.642	.461	.483	-.899	.544	.849	.981	-1.22	.347
-1. 81	-1.78	-.787	-.646	.407	.683	-.897	-.093	.902	1.43	-1.43	.430
-1.35	-.605	-.659	-.583	.490	.529	-.179	.478	.896	1.03	-1.12	.415
-1.41	-1.19	-.659	-.691	.453	.775	-.118	.120	.979	1.45	-1.31	.525
-.762	-.345	-.766	-.703	.465	.435	. 219	.628	.784	.102	-1.68	.417
-1.36	-.865	-.645	-.658	.427	.792	.012	.253	.997	.297	-1.81	.759
-.860	-.427	-.759	-.731	.460	.410	.042	.576	.786	.909	-1.58	.397
-1.76	-1.63	-.786	-. 603	.406	.779	.128	.0198	.924	1.49	-1.76	.679
$rmsT_S$=0.90 K								$rms\varepsilon_S$= 0.0257			

Table 7. Summary with 3 channel retrieval method

atmosphere								surface	retrieval errors in		
	T&W errors				R_u, R_d & t errors			es error	es	&	Ts
group	ΔT(K)	ΔW(%)	rmsT	rmsW	rmsRu	rmsRd	rms t	(rms es)$_a$	rmses	rmsTs	ΔTsmax
1	(-1.0 , 1.0)	(-5.0 , 5.0)	0.587K	2.94%	0.58%	0.60%	0.20%	0.0014	0.027	0.70 K	-1.89 K
2	(-1.0 , 1.0)	(-10.0,10.0)	0.587K	5.88%	0.98%	0.93%	0.44%	0.0019	0.027	0.76 K	-2.05 K
3	(-2.0 , 2.0)	(-10.0,10.0)	1.174K	5.88%	1.16%	1.21%	0.41%	0.0051	0.0233	0.78 K	-1.51 K
4	(-2.0 , 2.0)	(-15.0,15.0)	1.174K	8.82%	1.57%	1.54%	0.65%	0.0055	0.0234	0.80 K	-1.65 K
5	(-2.5 , 2.5)	(-20.0,20.0)	1.468K	11.76%	2.08%	2.03%	0.89%	0.0070	0.0236	0.80 K	-1.73 K
6	(-3.0 , 3.0)	(-30.0,30.0)	1.762K	17.64%	3.03%	2.88%	1.38%	0.0092	0.024	0.84 K	-1.93 K
7	(-2.0 , 0.0)	(-20.0,0.0)	1.174K	11.76%	8.17%	7.62%	3.62%	0.0150	0.0257	0.90 K	-2.05 K
8	(0.0 , 3.0)	(0.0, 30.0)	1.762K	17.64%	12.95%	11.91%	5.34%	0.0242	0.0352	1.12 K	-2.87 K
For all cases									0.0264	0.85 K	-2.87 K

Table 8. Summary with 2 channel retrieval method

atmosphere								surface	retrieval errors in		
	T&W errors				Ru, Rd & t errors			e_s error	e_s	&	Ts
group	ΔT(K)	ΔW(%)	rmsT	rmsW	rmsRu	rmsRd	rms t	(rms es)$_a$	rms e_s	rmsTs	ΔTsmax
1	(-1.0 , 1.0)	(-5.0 , 5.0)	0.587K	2.94%	0.54%	0.51%	0.25%	0.0011	0.0147	0.80 K	-1.74 K
2	(-1.0 , 1.0)	(-10.0,10.0)	0.587K	5.88%	1.01%	0.92%	0.53%	0.0018	0.0147	0.86 K	-1.99 K
3	(-2.0 , 2.0)	(-10.0,10.0)	1.174K	5.88%	1.08%	1.03%	0.50%	0.0023	0.0184	0.83 K	-2.64 K
4	(-2.0 , 2.0)	(-15.0,15.0)	1.174K	8.82%	1.56%	1.45%	0.79%	0.0028	0.0184	0.96 K	-2.67 K
5	(-2.5 , 2.5)	(-20.0,20.0)	1.468K	11.76%	2.09%	1.93%	1.07%	0.0037	0.0184	0.92 K	-2.66 K
6	(-3.0 , 3.0)	(-30.0,30.0)	1.762K	17.64%	3.13%	2.85%	1.67%	0.0057	0.0185	0.97 K	-2.69 K
7	(-2.0 , 0.0)	(-20.0, 0.0)	1.174K	11.76%	8.53%	7.79%	4.36%	0.0142	0.0167	1.08 K	-1.97 K
8	(0.0 , 3.0)	(0.0, 30.0)	1.762K	17.64%	13.45%	11.98%	6.44%	0.0219	0.0199	1.31 K	-3.41 K
For all cases									0.0176	0.99 K	-3.41 K

4. CONCLUSION

Accurate determination of land surface temperature from satellite measurements is of great importance and of wide practical application value, but accurate determination of land surface temperature is difficult, because of the atmospheric effect, the non-uniformity of land surfaces and the coupling between the land surface temperature and emissivity. The results of simulation tests concerning the atmospheric effects on retrieved land surface temperatures and emissivities show that the errors in atmospheric temperature and moisture profiles randomly distributed around their true values and of reasonable accuracies may not seriously affect the accuracies of retrieved land surface temperatures, and comparatively, the errors in atmospheric temperature and moisture profiles randomly distributed and systematically larger or smaller than their true values may have larger effect on the land surface temperatures retrieved. Usually, the errors of atmospheric temperature and moisture profiles retrieved from satellite radiative measurements are distributed randomly around their true values, so that it seems possible to retrieve land surface temperatures with acceptable accuracy by using atmospheric temperature and moisture profiles retrieved from satellite measurements in atmospheric correction.

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