The assimilation of AIRS radiance over land at Météo -France

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1. Introduction

With the gradual reduction of radiosonde coverage in some areas and for the data void areas, satellite data assimilation over land becomes more important. Accurate knowledge of the land surface characteristics is required for NWP radiance assimilation. For that purpose, an atlas of surface spectral emissivity (SSE) climatology has been developed at Meteo-France, which has 18 wavebands in the infrared spectral range and is available for each month. In this study we have two targets. The first is to start investigating the assimilation of AIRS radiances over land. The second is to assess the impact of the surface characteristics, emissivity and surface temperature, on the short-range synoptic scale forecast. To reach these targets, the ARPEGE 4D-Var system has been used to perform the analysis and the forecast.

2. The atlas of surface spectral emissivity climatology for AIRS

The emissivity spectra used in this study were taken from spectral libraries (MODIS, ASTER and JPL) compiled with the ones modelled by Snyder et al. (1998). New emissivity maps were produced separately for 18 wavebands in the infrared spectral range and for each month (Szczech-Gajewska and Rabier 2003). The new classification of surface type was based on the Ecoclimap, a complete surface parameter global dataset (Masson, 2003). Most of these ecosystems were a combination of only one of twelve vegetation types (so-called pure ecosystems) with addition to urban areas and water, which gave us full description of fourteen simplified global land cover types as Table 1.

AIRS is a grating spectrometer with 2378 channels at approximately 1 cm-1 resolutions covering the 3-15 *m spectral interval. For data transmission reasons the data volume was reduced, only one in every eighteen fields of view are used and thinned additionally by sampled 1/7 locations, and a subset of 324 channels was prepared by the NOAA AIRS Science Team. After channel selection, the total number is further reduced to 64 channels. (Table 2).

Table 1. Fourteen land cover types

Number	The surface type	Comment
1	bare soil	
2	rocks	
3	permanent snow and ice	
4	crops type C3	omnipresent except tropical and equatorial belts, and where the corn is intensively cultivated
5	crops type C4	applied for crops C3 exceptions
6	irrigated crops	
7	natural herbaceous	temperate
8	natural herbaceous	tropics
9	wetland herbaceous or irrigated grass	
10	needleaf trees	
11	evergreen broadleaf trees	
12	deciduous broadleaf trees	
13	urban areas	
14	Water	

Table 2. 64 channels in the infrared spectral range for AIRS at Meteo-France. Nr is the waveband number, band is the infrared spectral range of waveband

Nr	Band(cm³)	AIRS channels used
1	645-760	333 338 362 375
2	760-805	453 475 434
3	805-885	497 528 587 672
4	885-950	787 791 843 870
9	1210-1240	1301
10	1240-1968	1329 1371 1415 1434 1449 1455 1466 1477 1500 1519 1520 1538 1545 1565 1574 1583 1593 1627 1636 1652 1669 1694 1708 1723 1740 1748 1756 1771 1777 1783 1794 1800 1806 1826 1843 1852
15	2180-2450	1865 1866 1868 1869 1872 1873 1875 1876 1877 1881 1882 1911

Table 3. The percentage of "good points"

		Europe	Africa
00UTC	climatology	62.8	57.0
	constant	62.4	53.6
12UTC	climatology	52.0	44.3
	constant	51.6	46.9

Validation of the atlas of surface spectral emissivity climatology

Table 3 presents the statistic results of "good points" in the range from −2K to 2K for all of 324 channels before bias-correction over Europe and Africa. The atlas of surface spectral emissivity climatology has a positive impact on the forecasted brightness temperatures for both day and night time over Europe. The SSE improved noticeably the quality of simulated brightness temperature around local night, but it degraded significantly results around local noon over Africa. We think that the problem may come from the skin temperature, which is under-estimated around local noon.

3. PROCESSING OF AIRS RADIANCES OVER LAND

• The surface emissivity uses the new surface spectral emissivity climatological maps which have 18 wavebands in the infrared spectral range for each month with 14 land cover types over land. Over ocean, the surface emissivity is constant with the value equal to one.

• The channel selection used over land is the same as over ocean.

• The neural network bias correction is applied for each channel over land, i.e. the bias-correction scheme is the same as over ocean.

• Over land, if orographic altitude is higher than 1500m, all of the channels are rejected.

• The observation errors over land were preliminarily analysed. The results show that the value of the observation errors over ocean can be used over land too.

• Cloud detection is the same as over ocean, i.e. NESDIS cloud detection scheme is used (Goldberg et al., 2003).

4. EXPERIMENTS

Table 4. Experiments of four-dimensional variational data assimilation and forecast suite with AIRS observations

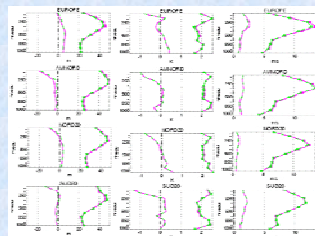| Num	Name	AIRS		SSE		T_sk adjusted around local noon over land
		ocean	land	ocean	land	
Exp.1	reference	used	no	constant		no
Exp.2	control	used	used	constant	climatological	no
Exp.3	emissivity	used	used	constant	constant	no
Exp.4	skin temperature	used	used	constant	climatological	adjusted

Fig.1 Root Means Square Error (RMSE) of Exp.1 and Exp.2 with respect to radiosondes by 72h, left column is geopotential, middle column is temperature, right column is wind. The X and Y axis represent RMSE values and the vertical pressure levels respectively. Exp.2 is represented in green, Exp.1 in red.

(a) The impact of AIRS observations over land on the accuracy of NWP

Figure 1 shows that the impact of AIRS observations over land on the quality of forecast is positive over the Northern Hemisphere, but slightly negative over the Southern Hemisphere
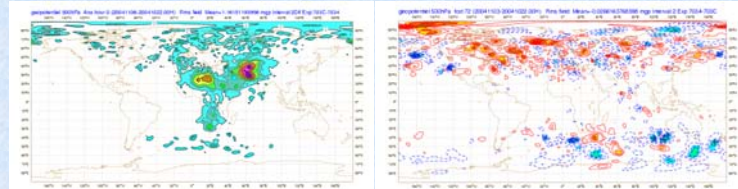

Fig.2 The root mean square difference between Exp.2 and Exp.1 analysis for the geopotential height at 500hPa, Interval: 2.0m, Unit: geopotential.

Fig.3 The differences (Exp.1 - Exp.2) of the root mean square error of geopotential height at 500hPa at 72h forecast, the red solid line is positive, the blue dash line is negative, Interval 2.0m; Unit: geopotential

Figure 2 shows that the differences between Exp.2 (with AIRS over land) and Exp.1 (without AIRS over land) analysis are rather large over Africa, Europe, the northern part of Northern America, Northern Atlantic, Middle Asia, western part of Russia and Arctic and the region of the large difference is a triangle shape, which results from the increase of AIRS observations over land

By 72h, the large positive differences cover mainly Northern America, Europe and Northeast Asia, the differences are small over Africa, positive and negative differences are distributed over the ocean of Southern Hemisphere and the negative values are more than the positive values over this region (Fig.3).
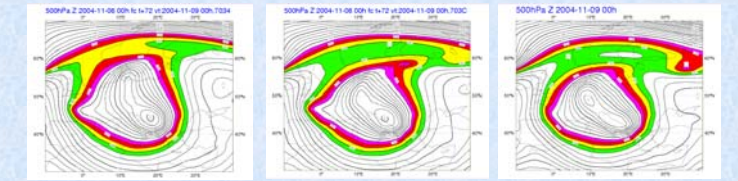

Fig.4 Geopotential at 500hPa for 9 November 2004. left panel is the forecast without AIRS data over land by 72h, mid panel is the forecast with AIRS data over land by 72h, right panel is the verifying analysis, The experiment with AIRS over land simulated successfully the trough (35°E,56°N), the pattern in Exp.2 is closer to verifying analysis than that in Exp.1

(b) The impact of surface spectral emissivity on the accuracy of NWP

	The impact of AIRS observations over land	The impact of surface spectral emissivity
300hPa	0.63	0.10
500hPa	0.41	0.14
850hPa	0.26	0.15

Table.5 The differences between experiments for the root mean square error of geopotential height at 500hPa by forecast 72h over the northern hemisphere . The values in the left column is the difference between Exp.1 and Exp.2, the values in the right column is the difference between Exp.3 and Exp.2. Positive values mean that Exp.2 improves the quality of forecast

Table 5 shows that impacts of both AIRS and new SSE over land are positive over the northern hemisphere, The impact of using AIRS over land with new SSE compared with no data over land is strong and increases with altitude. The impact of using AIRS with new SSE over land compared to AIRS with a constant emissivity is slightly positive and decreases with altitude.

(c) The impact of the skin temperature on the accuracy of NWP

The skin temperature in the operational suite has the problem of under-estimation around local noon.
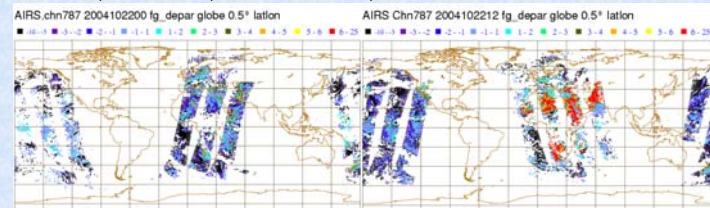

AIRS chn787 2004102200 fg_depar globe 0.5° lat/lon   AIRS Chn787 2004102212 fg_depar globe 0.5° lat/lon

Fig.5 The differences between observed and first guess brightness temperatures (obs-guess) for channel 787. left panel is at 00UTC, right panel is at 12UTC 22 October 2004. The big biases appeard around local noon (12UTC).

In this experiment (Exp.4) we supposed that the biases of the skin temperature appeared during local mid-day (10:00-14:00) and the biases reached their maximum at noon (13:00). The impact of the experiment with the skin temperature adjusted is neutral.

5. CONCLUSIONS

• The assimilation of AIRS radiances over land has some positive impact on the forecast quality over the northern Hemisphere, even though the scheme is very preliminary.

• The experiments of assimilation and forecast, using AIRS radiances over land, are sensitive to both SSE and the skin temperature. The assimilation of AIRS radiances with SSE is better than that with a constant emissivity equal to one over land. The skin temperature in the operational suite could have the problem of under-estimation around local noon.

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∗Snyder, R. 1998   Classification-based emissivity for land surface temperature measurement from space. Int. J. Remote Sensing, vol. 19, No.14, 2753-2774
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